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IALA

GUIDELINE

G1117
VHF DATA EXCHANGE SYSTEM (VDES) OVER-VIEW

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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. The latest edition of the Guideline is the only version in force unless the Guideline is explicitly revoked by the Council.

Date	Details	Approval
December 2016	Edition 1.0	Council 63
December 2017	Edition 2.0 Updated to reflect technical developments in VDES and to reflect transmission aspects (addressed / broadcast)	Council 65
December 2022	Edition 3.0 Whole document major update.	Council 76
June 2026	Edition 4.0 VPFI moved to a new Recommendation, updated to reflect technical developments in VDES and to reflect transmission aspects (addressed / broadcast)	Council 04

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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, the potential of VDES in the maritime environment, and the use cases supported by VDES.

The document is intended to assist in 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.

The Automatic Identification System (AIS) is well recognized and accepted as an important tool for the safety of navigation and is a carriage requirement for SOLAS vessels (Class-A) [2]. With an 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. The AIS can also transmit addressed messages.

The International Telecommunications Union (ITU) has recognized the necessity for efficient 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 addresses the identified need to protect and authenticate AIS, along with essential digital communications contributions for e-Navigation.

The VHF marine band [3] was initially used for the 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 the safety of navigation, the 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 with:

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

The introduction of VDES is expected to happen through the 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) on the 1st of January 2019 the VDES VHF channels should only be used digitally 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 a 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 incorporating changes to add VDES Satellite functionality and updates consequential to feasibility tests.

7 (2026) ITU has published ITU-R M.2092-2 [1] incorporating changes to adopt learnings from early tests.

8 (2026) IMO adopted the introduction of VHF data exchange system (VDES) into the IMO regulatory framework including appropriate SOLAS V amendments. [Secretariate: keep this in case MSC111 adopted VDES, otherwise remove this #8]

9 (2028) All the VDES VHF channels shall only be used for the VDES (MSC.1/Circ.1460/Rev.5*)* [8] globally.

10 (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 as 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.

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 could improve the safe and efficient movement of vessels for the benefit of maritime community and the protection of marine environment. 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 the exchange of digital data between ship to ship, ship to shore, including satellite, via AIS, ASM, and VDE-TER and VDE-SAT.

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

2.1. CONTRIBUTION OF VDES TO E-NAVIGATION

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] and MSC.1/Circ.1610 Rev.1.

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 improving 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.

Out of these Maritime Services, VDES is mostly designed to support:

- VTS Services
- Aids to Navigation Services
- Port Services
- Pilot and Tug Services
- Vessel Shore Reporting
- Ice and Meteorological Services
- Real-time hydrographic and environmental information Services
- SAR Services

VDES supports these by providing digital communication means and radionavigation capabilities.

2.2. SYSTEM CONCEPT

The system concept, including VDES functions and frequency usage, is illustrated pictorially in Figure 1 (full system).

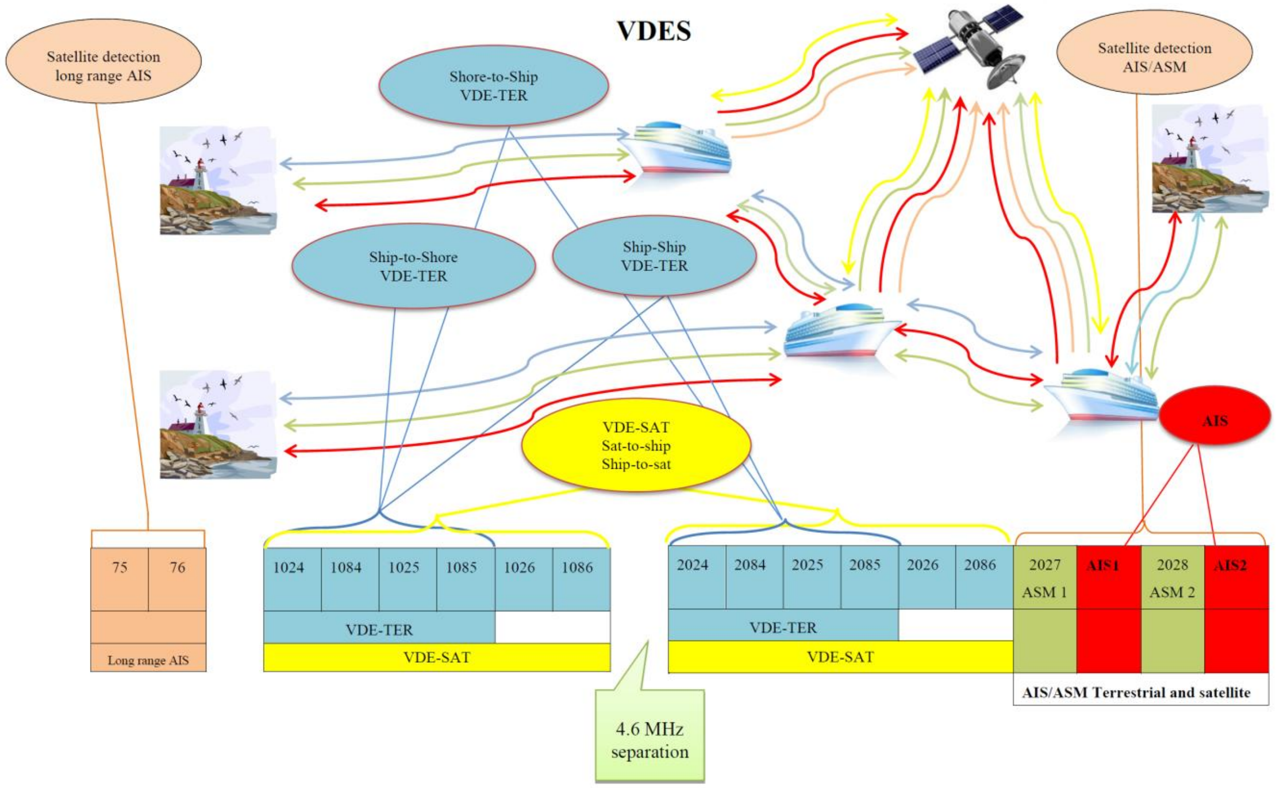

Figure 1 VDES functions and frequency use – full system

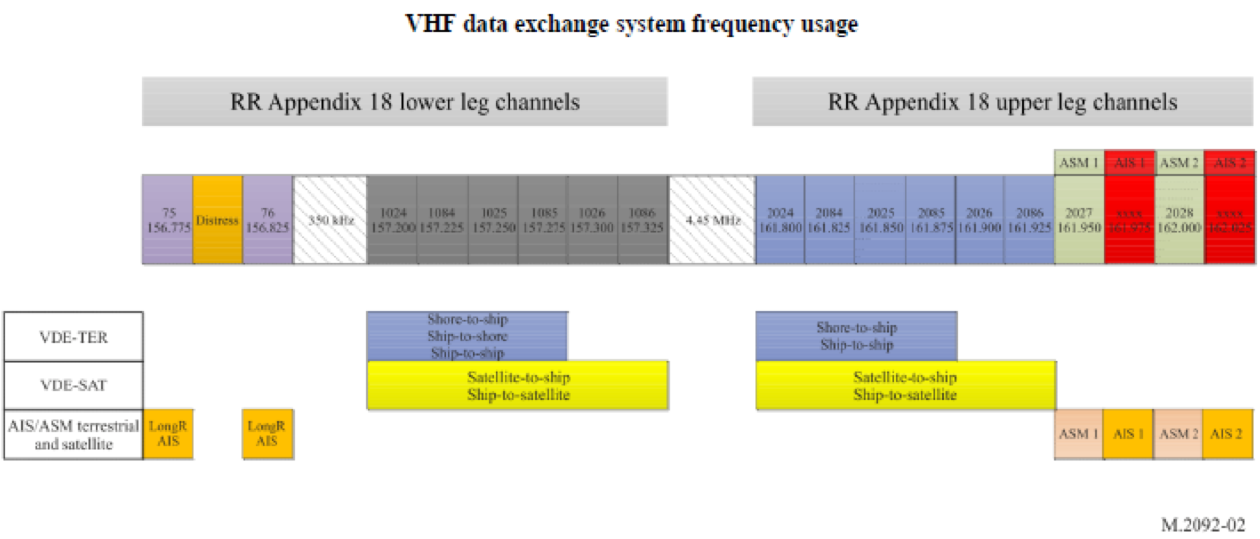

Figure 2 VDES frequency usage and frequency allocation to each component

2.3. 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 occur with the minimum involvement of ship's personnel.

6 The VDES includes AIS, ASM, VDE-TER, and VDE-SAT.

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

8 The VDES implements data integrity monitoring at the VDES link level (e.g., checksum).

9 The VDES-related applications address cybersecurity (e.g., authentication, key management, and, if required, encryption).

10 The VDES has a high level of availability.

11 The VDES supports machine-to-machine communications (for example, interfaces with external equipment providing applications related to VDES).

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

The concept of operations is identified in Figure 3.

2.4. OPERATIONAL CHARACTERISTICS

The VDES operates according to Recommendation ITU-R M.2092 [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 underway, 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.

2.5. VDES STATION TECHNICAL OVERVIEW

The VDES include:

- antennas, 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).

2.6. 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.

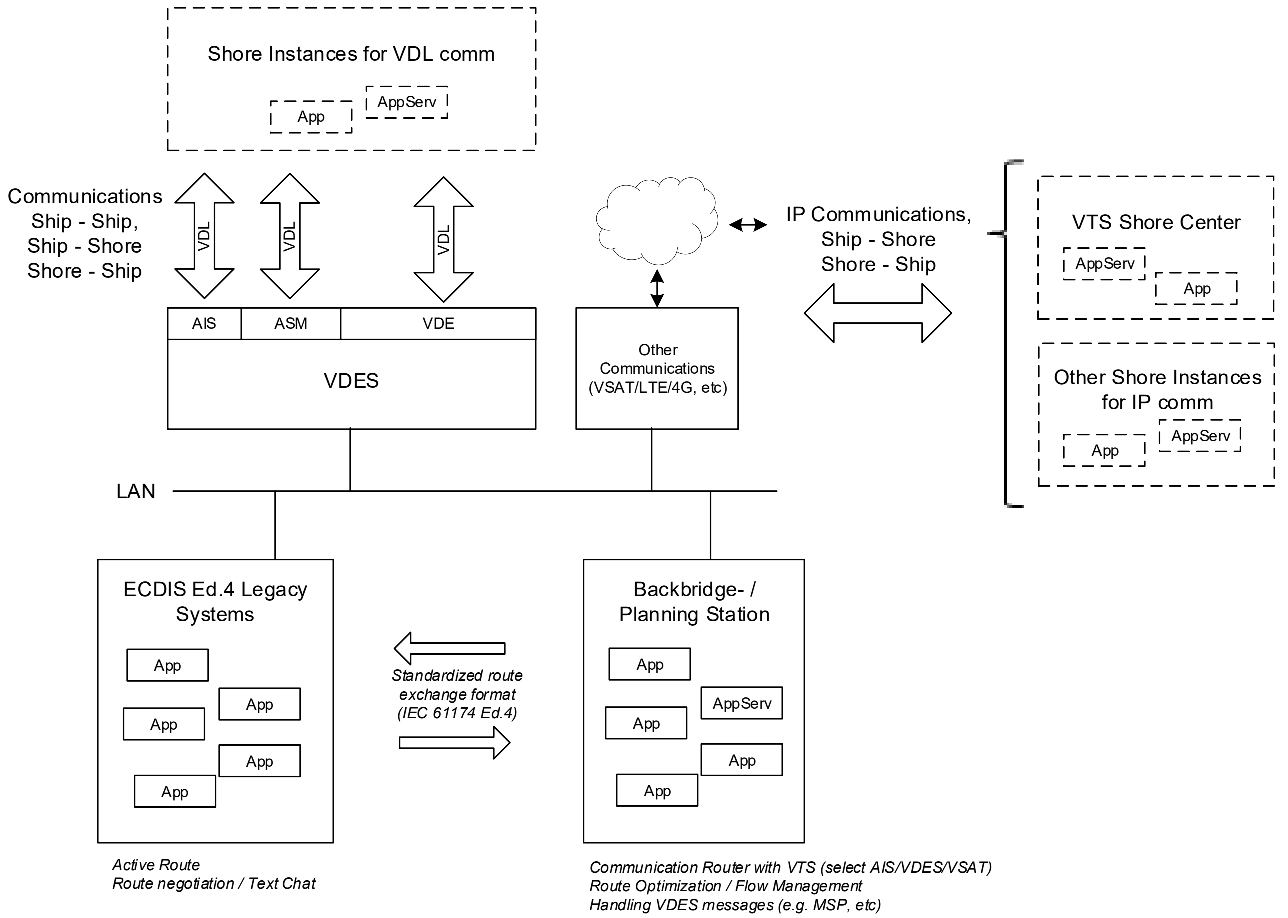

Figure 3 Concept for VDES

2.7. VDE PAYLOAD FORMAT IDENTIFIER

In order for applications to be able to identify the content of VDES messages, the Payload Format Identifier (VPFI) as described in Recommendation RNNNN [VPFI] should be used.

This method:

- is very flexible and makes it possible for 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 AIS messages and ASM formats and encodings, as defined by IMO and national authorities.

Therefore, this document assumes that the VDE-TER and VDE-SAT binary messages use the VPFI for 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, but may also use VPFI messages.

2.8. MAXIMUM PAYLOAD SIZES

The VDES PI supports message sizes of up to:

- 2 259 bytes broadcast / 2 199 bytes addressed / 157 bytes geographical multicast (ASM, see IEC 63514),

- 9800 Bytes (VDE-TER, see IEC 63514), and
- 10kB (VDE-SAT, see IEC 63514).

Applications that require larger payloads need to perform splitting into smaller payloads for reassembly.

2.9. PAYLOAD COMPRESSION

As VDES payloads are limited in size and the VDES VHF Link is limited in bandwidth, it is recommended to reduce all unnecessary overhead from payload data.

For example, S-124 data model-based navigational warnings are disseminated using GML over SECOM [38]. On the data model side, when generating the GML data representation, taking into account:

a the possibility to reduce the precision of geographical coordinates to the necessary minimum number of decimals in coordinates, and

b the possibility to reduce the number of polygon edges, to simplify geometries to the necessary,

c the possibility to use XLink geometries, as described in S-100 Part 10b, to use referencing of geometries that are used multiple times inside the data, instead of inline geometry definitions in the objects.

After GML is generated, on the transport side, the following compression may be taken into account:

a SECOM [38] Table 16 defined [envelopeUploadObject], containing the zipped S100_ExchangeSet, which contains the GML, and

b the possibility to compress GML even better by use of the W3C EXI (Efficient XML Interchange), which was discussed by IHO S-100 working groups, but not adopted for the S-100 documentation. EXI can be used in an informed mode, i.e., knowing the XML Schema of the GML data, then much of the overhead can be saved. This, however, requires a clear definition of formats on the shore and ship side. The MCP MMS working group is considering the use of EXI in the SECOM Gateway (shore) and SECOM Agent (on ship).

2.10. INTERFACING WITH BRIDGE EQUIPMENT

Bridge equipment, such as ECDIS, is interfacing with a VDES receiver through IEC 61162-450.

The IEC TC80 MT7 for ECIDS together with WG17 defines a new ECIDS interface towards SECOM [38], which allows the transfer of S-100 based payloads. It will be part of the new SECOM standard edition expected to be published in 2027 and should be considered by application gateway developers that bridge VDES into the world of ECDIS.

This interface also can be used by an MMS Agent on board of the ship to provide SECOM access for an ECDIS via MMS, i.e. through resilient connection pooling over internet and VDES.

2.11. SECURITY OPTIONS

Authentication of messages is an important feature which VDES can offer as defined in IEC 63514 [53]. Authentication provided by VDES signed segment authentication enables the receiver of messages to validate the authenticity of the sender and the integrity of the data.

VDES delivers authentication of AIS through the Encapsulated AIS messages defined in Recommendation RNNNN [VPFI] for VPFI 0.

In the future, standards may take into account broadcast authentication protocols like 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.

Further VDES Authentication concepts are described in Guideline G1192 [43].

3. IALA TEST BEDS

IALA provides a list of test beds that have been and are under development by administrations and industry (refer to IALA website).

4. PLATFORMS FOR THE PROVISION OF MARITIME SERVICES

4.1. 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), see IALA Guideline G1183;
- Maritime Service Registry (MSR), see IALA Guideline G1191; and
- Maritime Messaging Service (MMS), see RTCM Standard 13900.0 [40].

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 key 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
- 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.

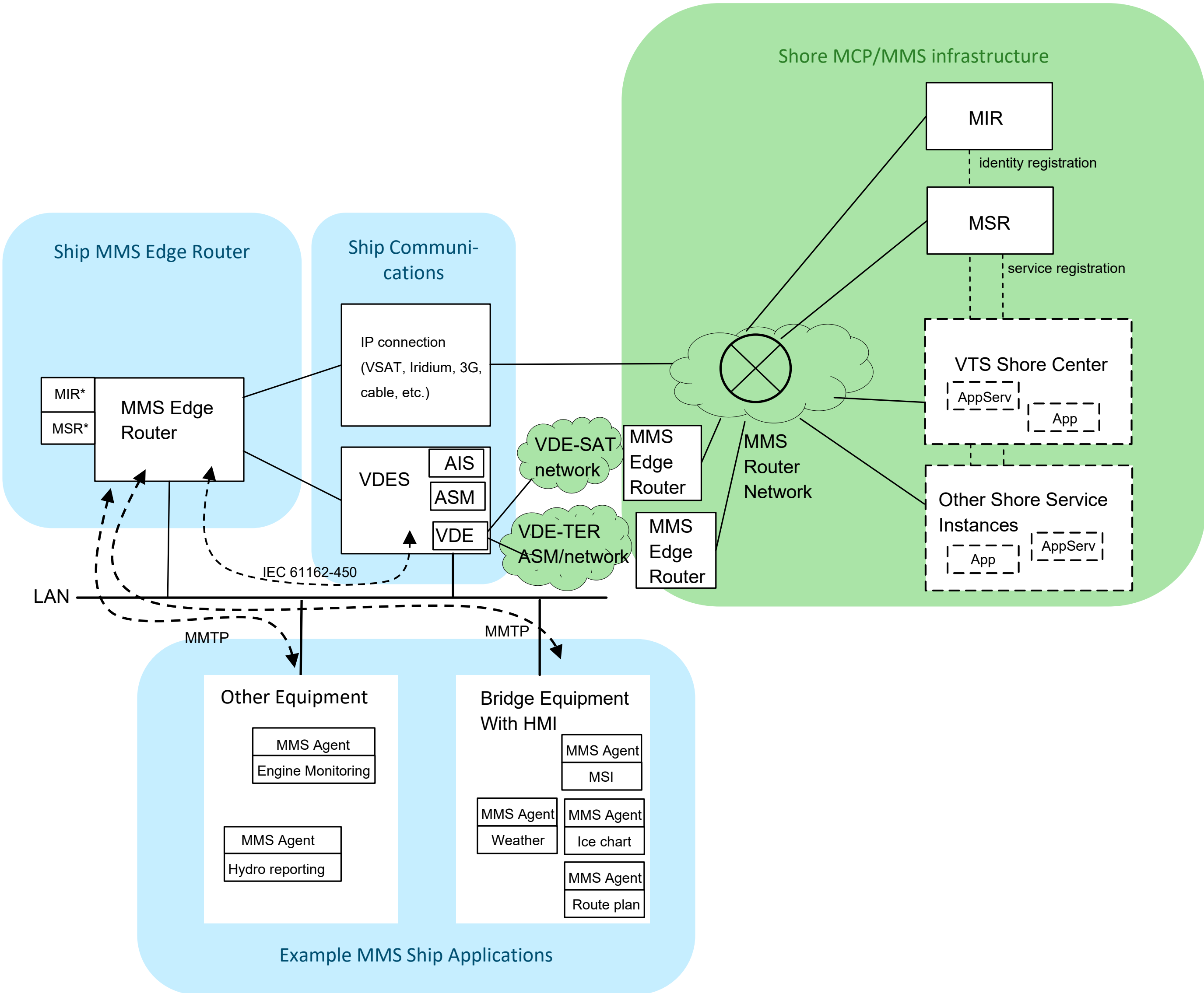

Figure 4 MMS with VDES, example System Overview

4.1.1. THE MMS ARCHITECTURE

In the MMS, all communication between applications happen 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, communicating 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 internet connection (WIFI, satcom, IMT 3/4/5/6G); or

b through non-internet based communication and their respective shore side MMS Edge Routers (VDE-TER, VDE-SAT).

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 Transfer 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 the RTCM Standard 13900.0 on Maritime Messaging Service Architecture and Protocol [40].

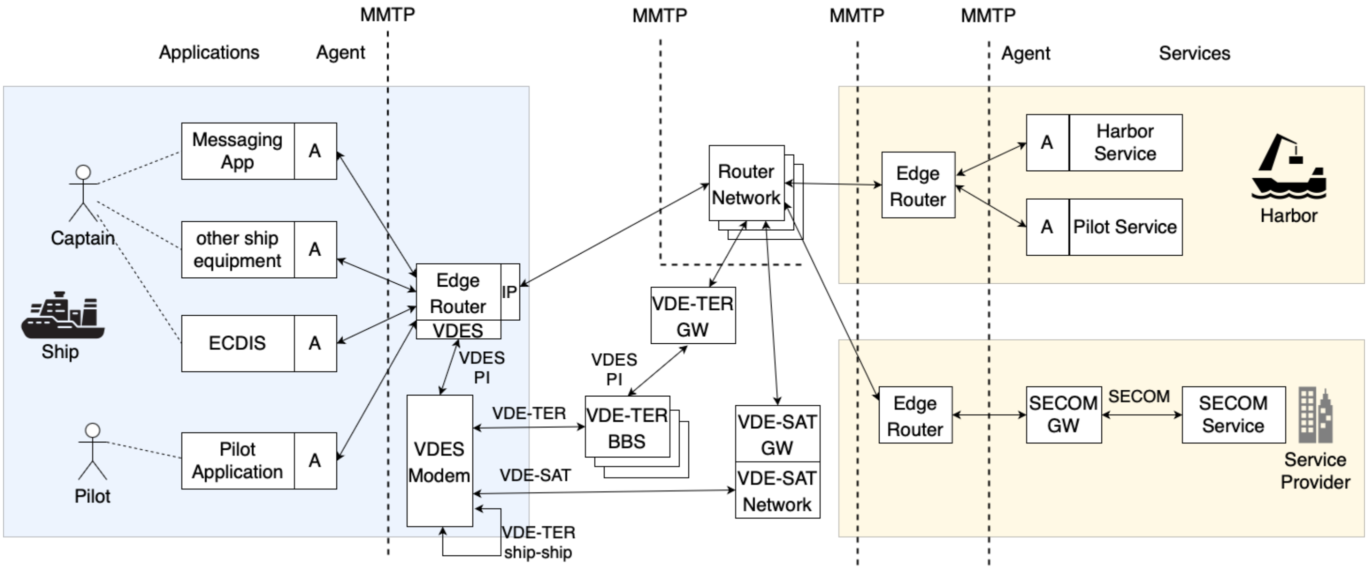

Figure 5 The MMS communication architecture with example applications

4.1.2. STATUS OF MARITIME MESSAGING SERVICE

The MMS is a published RTCM Standard [40] since 2025.

The MMS is used in the Korean VOOST, the European MaDaMe and Nelson projects, as just 3 examples.

The MMS is also named in the documents created by the IMO NCSR correspondence group on the "IP Connectivity Framework" for the S-100 infrastructure, as an optional way to transport S-100 information, supporting SECOM on shore and ship side.

5. VDES USE CSES IN THE CONTEXT OF IALAVDES USECASES IN THE CONTEXT OF IALA

5.1. AUTHENTICATION OF VDES MESSAGES

Today, AIS messages are broadcasted without authentication by ships, shore based infrastructure and AIS AtoN stations through AIS. Without authentication, there is no way for the recipient to verify the content of the received messages. The resulting problem is the now frequently reported as “AIS spoofing”.

The authentication of messages over ASM, VDE-TER and VDE-SAT allows to enable receivers to validate the authenticity of the sender of a message and the integrity of the message.

The upcoming Guidelines on shore-based VDES infrastructure and VDES Authentication will guide shore authorities on how to achieve AIS authentication in detail.

5.2. AUTHENTICATION OF AIS POSITION REPORTS

The authentication of VDES messages extends to the retransmission of AIS position reports as well as the static and voyage related ship data reports over VDE-TER to authenticate the AIS, as required by IMO in the draft VDES Performance Standards [55]. IEC 63514 [53] describes in detail how to conform to the IMO requirement and test it in VDES mobile equipment.

5.3. ATON

VDES is a communication means to authenticate AtoN AIS reports and to transmit the AtoN information by VDE.

Receiving VDES stations can validate the authenticity of the sender of a message and the integrity of the message. This resolves the current uncertainty regarding the cybersecurity aspects of received messages, such as virtual AtoN reports or other information that has only a digital representation and cannot be verified by other means.

5.4. VDES R-MODE

VDES can be used to provide ranging signals allowing vessels determine their position and time using R-mode when GNSS performance is degraded as it is detailed in Guideline G1158 [39].

5.5. 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.

Real-time information on meteorological and hydrographical information may be transferred via VDES.

In this use case, information shall be transmitted in standardized formats that can take advantage of the VDES capabilities, for example - IHO S-100 format.

Note: While VDES is technically capable to transmit safety related information, the IMO regulatory framework for VDES should be followed.

5.5.1. 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.

5.5.2. 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 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.

5.5.3. 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.

5.6. 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 [34].

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.

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 and interact with other port agencies (allied services).

Ports may also provide a local port service where it is deemed necessary through a risk assessment.

Specifically VTS may make use of S-421 route plan exchange and S-212 VTS digital service data models and transport the encoded and compressed[1] data over SECOM, MMS and IP and/or VDES between ships and shore, see Figure 10.

1 Data compression as described in IHO S-100, Part 10

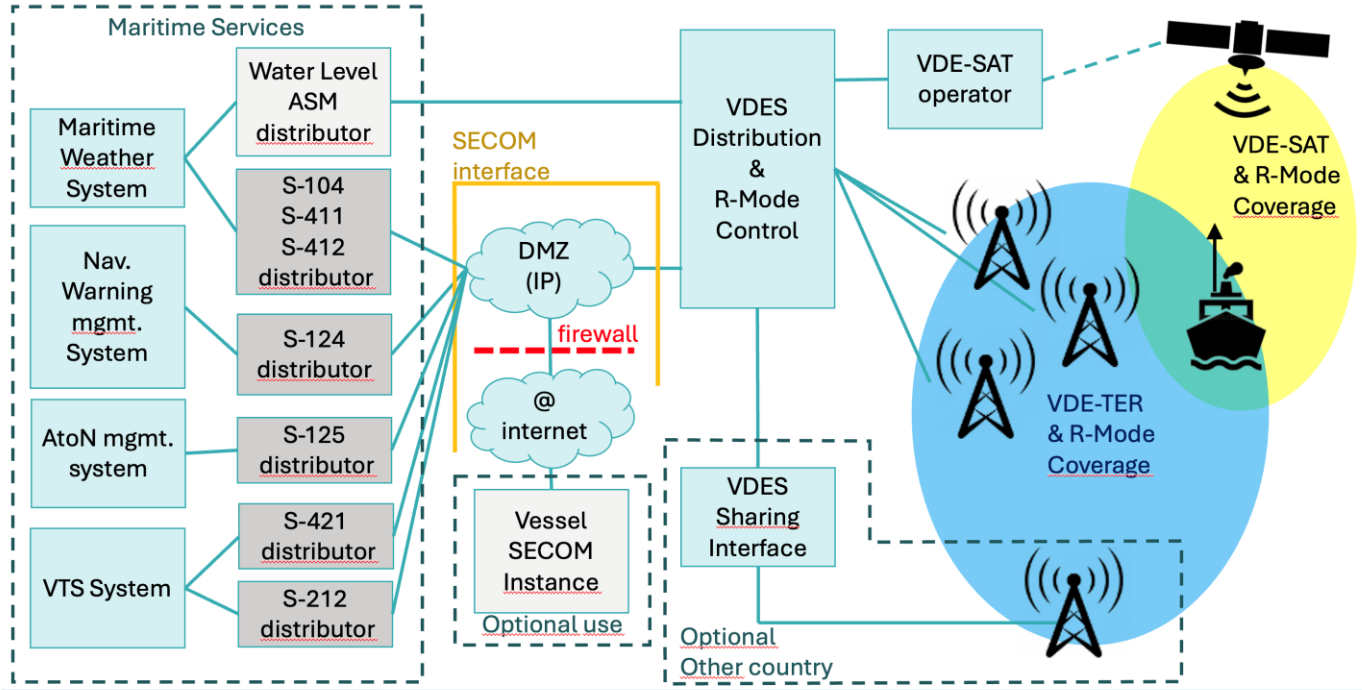

Figure 6 VTS and other maritime services over SECOM and VDES, example architecture using MMS in the VDES Distribution and on ship side.

5.6.1. 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.

5.6.2. SCENARIO - VTS PROVISION OF TIMELY AND RELEVANT INFORMATION

VTS provides timely and relevant information by broadcasting it 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. Timely exchange of information to support coordinated shipping operations will reduce potential risks. Computer-based automated notification between ships is useful. Further, as noted in section 6.7 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.

5.6.3. SCENARIO - VTS MONITORING AND MANAGEMENT

A VTS monitors and manages ship traffic to ensure the safety and efficiency of ship movements including for example planning ship movements, organizing ships under way and providing route advice. Monitoring and managing ship traffic 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 monitoring and management. Information exchange may be integrated with and portrayed on, external systems ashore and on-board.

5.6.4. SCENARIO - VTS RESPONSE TO DEVELOPING UNSAFE SITUATIONS

VTS responds to developing unsafe situations in order 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.

5.7. 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.

The reception of authenticated AIS transmissions through VDES also is part of MDA, see 2.8.

6. OTHER POTENTIAL VDES USE CASES

The listed use cases of VDES in this Guideline 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 1. Other potential use cases of VDES are presented in Table 2.

Table 1 Potential VDES Uses cross-referenced to IMO SN.1/Circ.1610 Rev.1

Potential uses of VDES	MS in the context of e-Navigation Reference
AtoN	MS 2 – Aids to navigation service (AtoN) (including PNT and Satellite Based Augmentation System)
SAR Communications	MS 16 - Search and Rescue (SAR) Service
Meteorological Services	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
Vessel Traffic Services	MS 1 – Vessel traffic service (VTS) MS 2 - Aids to navigation service (AtoN) (including PNT and Satellite Based Augmentation System) 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

Potential uses of VDES	MS in the context of e-Navigation Reference
Route Plan Exchange	MS 1 - Vessel traffic service (VTS) MS 2 - Aids to navigation service (AtoN) (including PNT and Satellite Based Augmentation System) 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 2 Other potential VDES Uses

Potential uses of VDES	New services that may utilize VDES
Loss of GNSS (PNT)	R-Mode (provides backup PNT)
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.
MASS	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.

6.1. INTEGRITY CHECK / AUTHENTICATION

VDES comprises AIS, ASM, VDE-TER and VDE-SAT with different data rate capabilities. AIS has no capabilities to authenticate the data for the receiver.

6.1.1. 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 the port of fish unloading and the 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.

6.2. 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 and other vessels for the exchange of intentions, e.g. route plan. The format of data will be defined/specified by other technical standards (ISO, IEC). A regulatory framework for MASS will be established by the IMO.

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

6.3. POSITIONING, NAVIGATION AND TIMING

GNSS as well as other radionavigation system and data services (e.g. DGNSS, SBAS) are vulnerable to intentional/unintentional interferences and common failure mode. Thus, to increase the level of PNT resilience there are different alternatives available such as the use of multi-system shipborne radionavigation receivers (see IMO Resolution MSC.401(95) [13]). The use of augmentation systems (SBAS/GBAS), the use of Receiver Autonomous Integrity Monitoring (RAIM) algorithms for maritime implemented at receiver level, the provision of redundancy of the Electronic Position Fixing System (EPFS), the use of R-mode or new GNSS services., Galileo High accuracy service (HAS) and Galileo Open Service Navigation Message Authentication (OS-NMA) among others. VDES is a technology that contributes to minimize the sources of vulnerabilities on board such as GNSS and AIS.

VDES R-Mode is an alternative PNT system based on VDES. VDES can be used to retransmit GNSS augmentation data.

6.3.1. Scenario – Retransmission of SBAS (GNSS) augmentation data

SBAS provides increased accuracy and integrity to GNSS services. Guideline G1152 SBAS Maritime Service introduces the main common elements. This section introduces alternative methods to distribute SBAS to ships using VDES.

6.3.1.1. SBAS retransmission through IALA DGNSS and AIS stations

In addition to the broadcast of SBAS corrections through the Signal-in-Space (SiS) in L1 frequency, these corrections can be used also as a source of differential corrections retransmitted using Medium Frequency (MF) IALA beacons and AIS stations (specifically for AIS it is done using AIS Message#17). At this stage, there are several IALA and AIS stations in Europe that are using SBAS as a primary or back-up data source for DGNSS, following the methodology and rules fixed in the Guideline G1129 The Retransmission of SBAS Corrections Using MF-Radio Beacon and AIS. Differential GNSS data in the reference location is computed by comparison of the SBAS-derived pseudo range with the observed measurement and converted in RTCM (Radio Technical Commission Maritime) 10402 format [51]. Finally, it is transmitted by Medium Frequency (MF) IALA beacons or AIS stations.

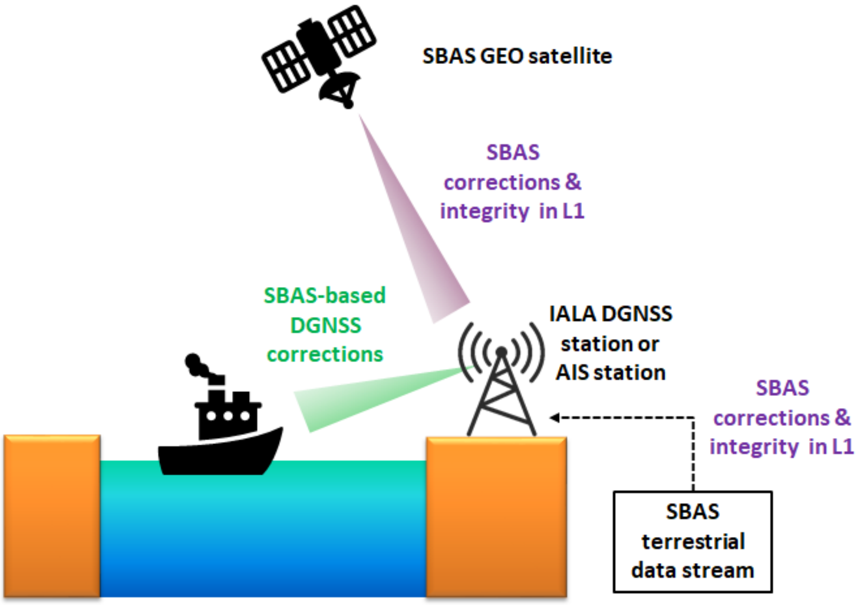

Figure 7 SBAS data retransmission through IALA DGNSS and AIS stations

If available, SBAS corrections can be also received through terrestrial data streams, i.e. EDAS service provided by EGNOS in Europe.

6.3.1.2. SBAS retransmission through VDES

VDES is an alternative to SBAS SiS in order to support SBAS DFMC, retransmitting SBAS L1 corrections but also the forthcoming SBAS L5 corrections (SBAS DFMC).

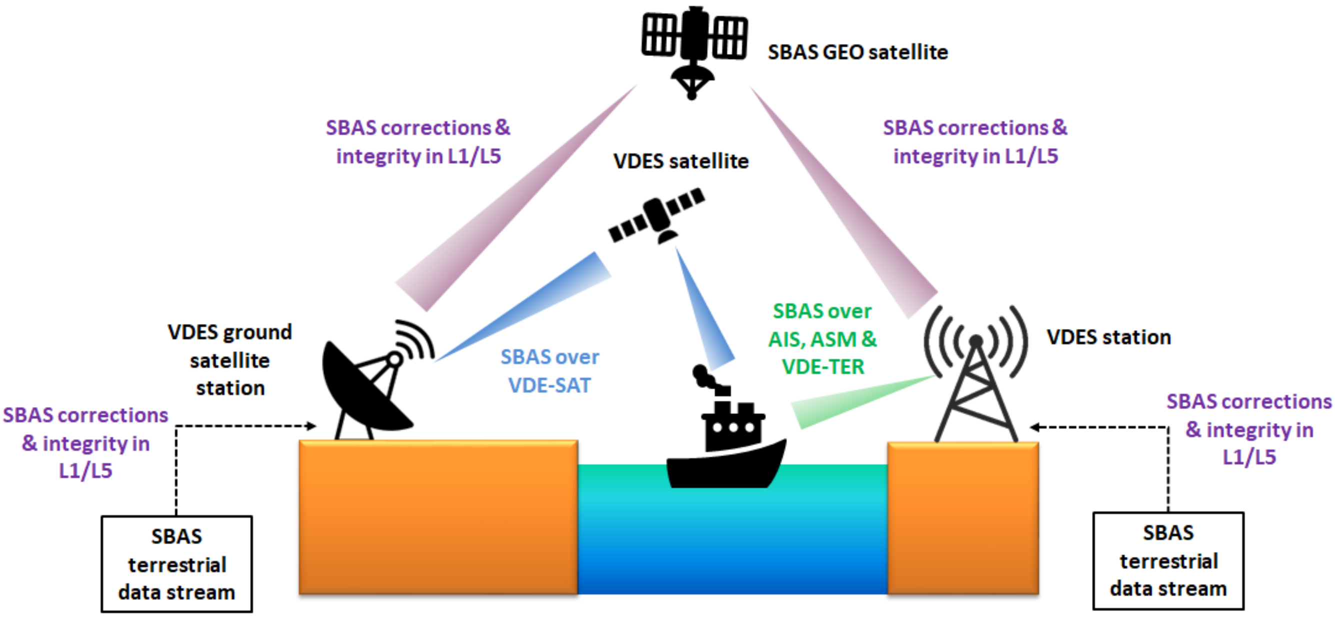

Figure 8 SBAS data retransmission through VDES channels

6.3.2. Scenario – Broadcasting RTK Correction data

High-precision navigation operations utilizing Real-Time Kinematic (RTK) correction data can be supported by a surveyed reference station providing RTK correction data to be transmitted by a VDES shore station. This functionality is currently provided by low bandwidth legacy radio equipment, but it is often not capable of providing all the correction data from the large amount of operational GNSS satellites. Using VDE-TER a shore station can transmit local RTK correction data of multiple GNSS constellations within a single slot every second. This provides redundancy from multiple constellations and can support high precision navigation operations in ports, locks and canals.

6.3.3. Scenario – GNSS Authentication

As presented in the Guideline G1192 on VDES authentication techniques, GNSS is a supporting infrastructure that provides the precise positioning and timing required for VDES operation. GNSS interference can disrupt accurate transmission timing within the VDES time frame structure and prevent accurate position reporting by VDES equipped vessels. The Guideline identifies attack vectors relevant to VDES, like jamming, spoofing and meaconing, that are analogous to the equivalent GNSS interferences.

GNSS authentication can play a role in maritime navigation. This protection layer supports not only the PNT in GNSS, but also the VDES communications. GNSS authentication is provided by Galileo OSNMA, as a free of charge service, with the positioning accuracy of the Galileo Open Service (OS), in the single frequency mode (E1). OSNMA authenticates samples of the navigation data that are used to compute the position, velocity and timing at the receiver.

6.4. 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 navigational, weather and other maritime warnings 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 VDE-SAT may deliver information in a broadcast 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.

As a communications medium VDES may be used to relay distress alerts, search patterns 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 at IMO.

In this use case the mix of current communications and developing communications techniques can enhance and improve the sharing of information during a SAR incident. This would include text in free form/ standard formats, transfer of waypoints/route plan information [2] for display on on-board equipment, transfer of GIS information/search patterns, small still images, etc.

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

6.5. SHIP REPORTING

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 and the 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]. Ship reporting may include voluntary reports for a number of purposes by vessels to various shore authorities.

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

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.

6.5.1. 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.

6.5.2. 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 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.

6.5.3. SCENARIO - SECURE SHIP REPORTING

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

6.5.4. SCENARIO - INTEGRITY OF GNSS POSITION REPORTING

GNSS interference or status may be reported by the ship via VDES.

6.5.5. 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 related to 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.

6.5.6. 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 the 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 [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 the vertical component of the GNSS position, but this might be an option in the future providing shore authorities with more useful information. In addition to the 3D position, the 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).

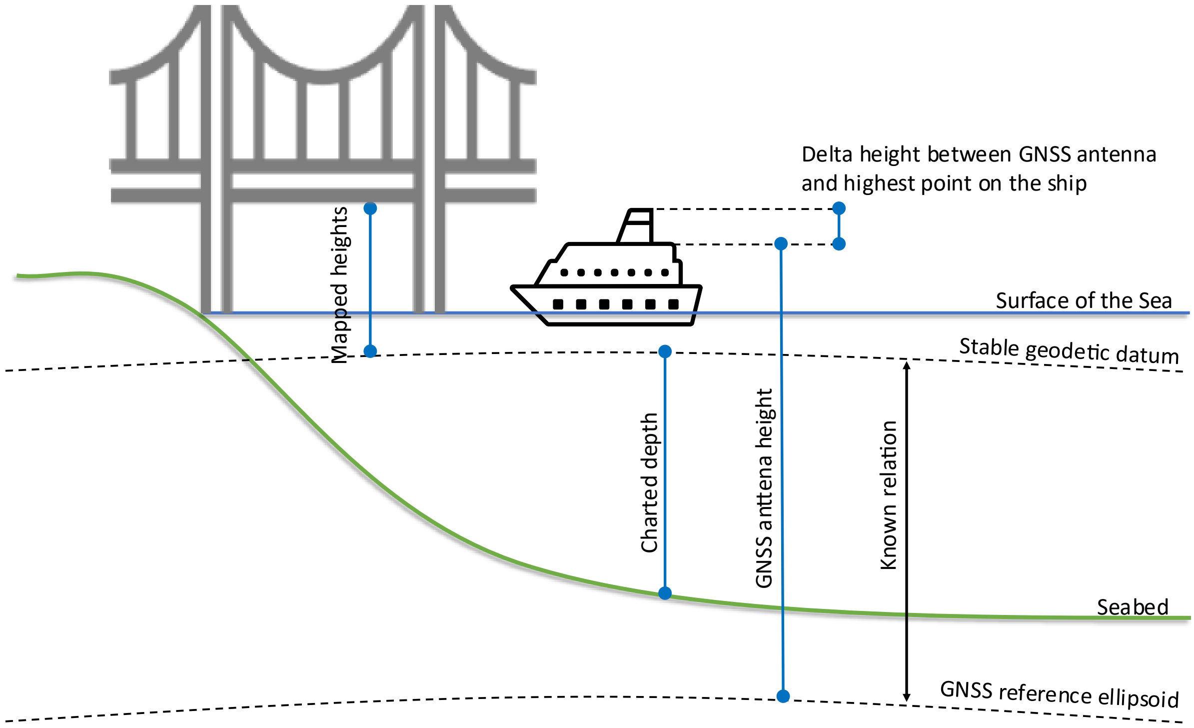

Figure 9 Bridge Clearance for Ships

It is suggested to include a field in the VDES message indicating if the 3D position is authenticated, following the recommendation on the IMO 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).

6.5.7. 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].

6.6. CHARTS AND PUBLICATIONS

IMO SOLAS Chapter V, Regulation 27 on 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 physical Marine 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.

6.6.1. 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 to 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.

6.6.2. 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.

6.7. ROUTE PLAN 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 plan 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, e.g. possible malfunction. The use of route plan 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 plan exchange could assist with route and speed optimization based on weather and currents, just in time arrival, and traffic congestion. Route plan exchange could take advantage of the addressed and broadcast aspects of VDES. Details for route plan exchange are specified by IEC 61174 [36] edition 4 annex S and IEC 63173-1 [37].

6.7.1. SCENARIO - SHIP TO SHORE

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

6.7.2. 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.

6.7.3. SCENARIO - SHIP TO SHIP

Ship to ship exchange could be sequential, i.e. allowing a route to be exchanged between stations via message forwarding including multiple hops such as stations in between Ship to ship route plan exchange could 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 the exchange of intentions. Route plan 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 understand and clarify the intention of the operation of the ships involved to avoid a collision. VDES provides direct ship-ship communication when meeting at sea without dependency to other infrastructure. In addition, as automatic translation/interpretation is introduced in this system, the communication can take place in different languages. For existing systems it takes a longer time to establish such communication. firstly, the ship's call sign is obtained by AIS and secondly, the ship needs to be called 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.)

6.7.4. 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 situation or incident and to propose alternate routing or other measures to the vessel or vessels throughout the incident.

6.8. LOGISTICS / SERVICES

There are several logistical aspects when sailing from berth to berth that must be addressed before, during and after the voyage . Most of these are taken care of by an agent on-shore. 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 could be the preferred communication exchange platform.

Information transfer could assist with efficiency of the overall cargo chain. The standard data model 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 aspects of VDES.

Sharing of route plan 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.

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

6.8.1. SCENARIO - LOGISTIC SERVICES – SHIP TO SHORE

A ship planning arrival at a port communicates the revised time of arrival and requests for stores, fuel and access to waste facilities which may be requiring confirmation from the port services. The vessel also may request 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.

6.8.2. 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.

6.9. 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 would be covered by that category. When terrestrial communications infrastructure is damaged by a natural disaster, VDES satellites can provide a communications link to meet emergency information exchange 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.

7. 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.

8. ABBREVIATIONS

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
ECDIS	Electronic Chart display & Information System
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
kbps	kilobits per second
LPS	Local Port Service
MCS	Modulation and Coding Scheme
METAREA	Geographical sea region for the purpose of co-ordinating the transmission of meteorological information
MIR	Maritime Identity Registry
MMS	Maritime Messaging Service
MMSI	Maritime Mobile Service Identity
MSI	Maritime Safety Information

MSP	Maritime Service Portfolio
MSR	Maritime Service Registry
NACK	Not Acknowledgement
NAVAREA	Geographic area in which various governments are responsible for navigation and weather warnings
NAVTEX	Navigational Telex (service)
PI	Presentation Interface
PSK	Phase-Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keying
RA	Random Access
RACH	Random Access Channel
SBAS	Satellite Based Augmentation System
SIP	Strategic Implementation Plan
TBB	Terrestrial Bulletin Board
TDMA	Time-division multiple access
UDCH	User Data Channel
VDE	VHF Data Exchange
VDES	VHF Data Exchange System
VDL	VHF Data Link

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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 3 below).

AIS and ASM are simplex channels which can carry traffic in one direction at a time. VDE-TER lower leg and VDE-TER upper leg allow 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:

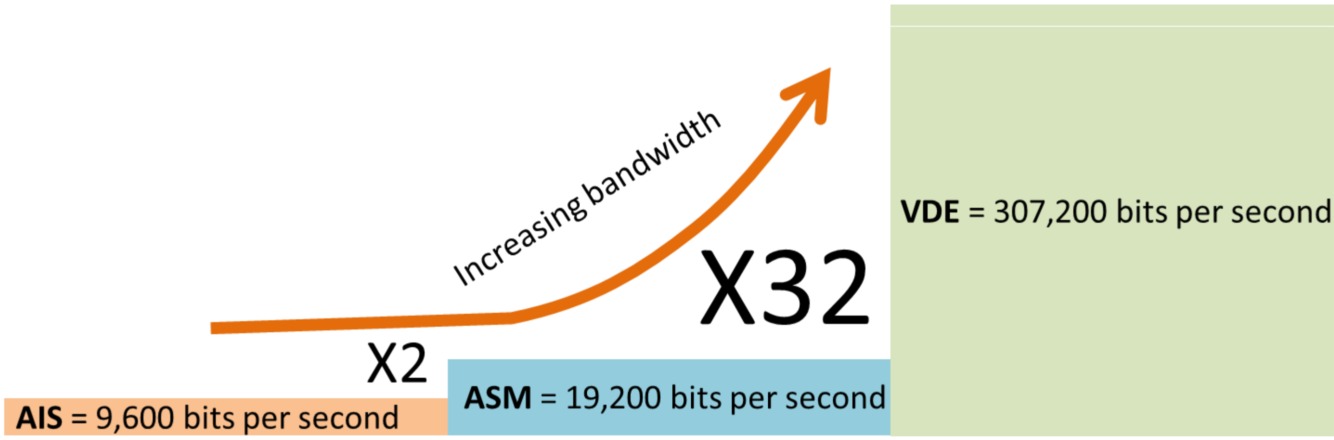
Technology	Radio Frequencies used	Radio Regulations channel number
AIS 1	161.975 (25kHz)	AIS 1 (2087)
AIS 2	162.025 (25kHz)	AIS 2 (2088)
AIS Long Range 1	156.775 (25kHz) (ships are TX only)	75
AIS Long range 2	156.825 (25kHz) (ships are TX only)	76
ASM 1	161.950 (25kHz)	ASM 1 (2027)
ASM 2	162.000 (25kHz)	ASM 2 (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 3 Frequencies allocated to VDES

A.2.3. THE DATA BIT RATE

The modulation schemes π/4-QPSK (ASM and VDE), 16-QAM (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 10.

Figure 10 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 217.7 kbps (Link Id 19) and VDE-SAT has a maximum raw transfer rates of up to 21 kbps (downlink Link Id 34) and 94.70 kbps (uplink Link Id 24). 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 the five logical channel types, the User Data Channel (UDCH), is dynamically allocated. The TBB , Assignment Channel (ASC) and Random Access Channel (RACH) are defined to ensure that the VDE channel is optimally used to carry user data. >Terrestrial VDE Channel resources are managed as logical channels. One of the 5 logical channel types, the User Data Channel (UDCH), is dynamically allocated. The TBB , Assignment Channel (ASC) 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 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], 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 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 antennas. A logical diagram of a VDES station with combined antenna is shown in Figure 11.

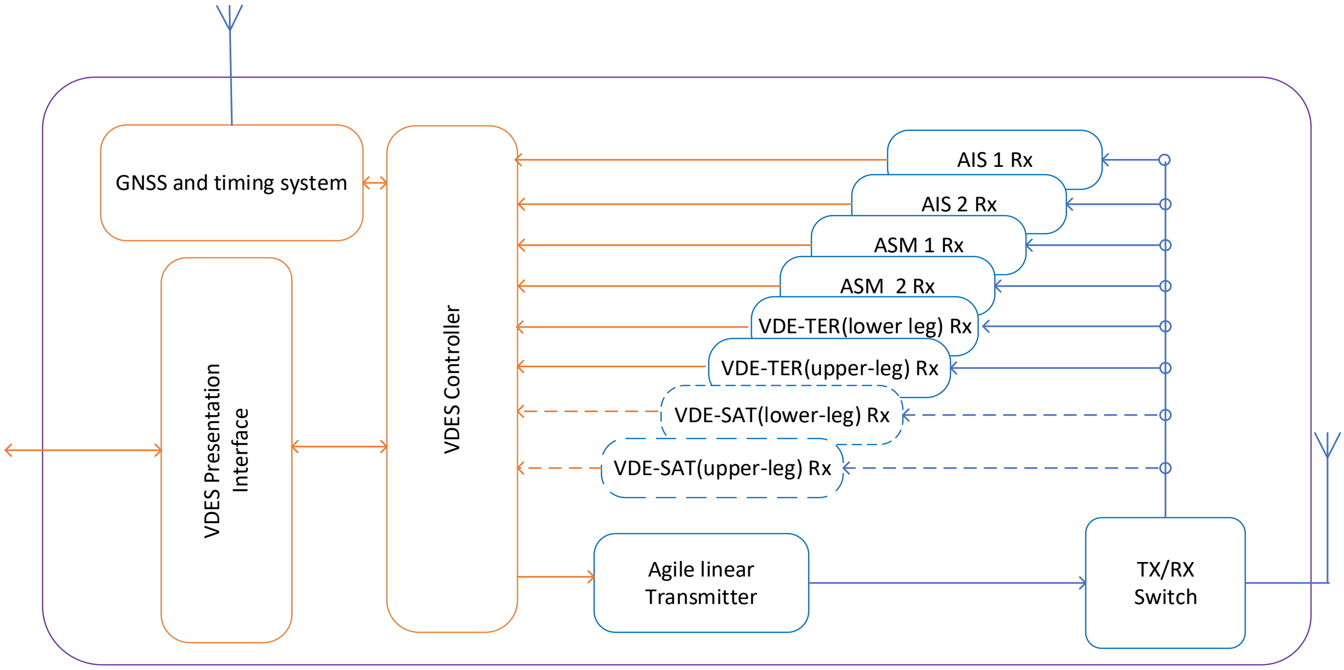


Figure 11 Logical description of VDES station, where VDE-SAT (dotted lines) may not be relevant for shore control stations.

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 is 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 4 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 4 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
7	ASM Data link management message	This message is used to broadcast FATDMA reservations for ASM.	RATDMA FATMDA	None