D1.15
Draft Chapter 4 (e-Navigation) for the 2018 Edition of the IALA NAVGUIDE

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Contents

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Background

The contents of this document will be used to update the IALA NAVGUIDE in relation to EfficienSea2 work on the VHF Data Exchange System (VDES). It contains a draft Chapter 4 (E-Navigation) for the 2018 Edition of the IALA NAVGUIDE. This is a working paper at the conclusion of IALA ENAV 20.

7 Communications

7.1 Introduction

The e-Navigation concept will increase the efficiency, safety and security of voyage planning and information in the maritime sector. e-Navigation is dependent on applications which provide mariners with the data they need in a more secure and efficient manner. These applications require communication technologies that can provide the necessary capacity for bidirectional ship-ship and ship-shore, including ship-satellite communication.

The role of communications as a cornerstone in safety was highlighted with the sinking of the Titanic in 1912. The two Marconi radio operators, Jack Philips and Harold Bride, transmitted the first SOS, which resulted in rescue of 1813 persons. Effective and efficient radio-communications at sea are connected with the safety of life, protection of the environment, efficiency of shipping movements and support for maritime Search and Rescue (SAR).

The 9 GMDSS functional requirements cover not only distress alerts and SAR communications but also Maritime Safety Communication (MSI), general radio communications as well as bridge to bridge communications. Public Correspondence and FAL forms transmitting are for instance covered under general radio-communications. The 4 levels of priority in radio-communications are described in the ITU Radio-communication Regulation: Distress, Urgency, Safety and other communications.

7.2 Digital Communications

Digital communications permeate our daily lives – both for work and for recreation. The introduction of 'any-time, any-where' access to information through the internet; text based or image based communications; geospatial locating and more is driving demand for faster, more robust, and more integrated, communication solutions.

Almost every e-Navigation solution currently foreseen depends upon efficient and robust ship-ship, ship-shore or shore-ship electronic data transfer. Existing communications systems may, in many places, be adequate to serve these needs, but it may be necessary to develop new methods to realise the full potential of e-Navigation. The performance requirements, in particular data capacity, for communications systems to support e-Navigation are, in many cases, unknown and are likely to change over time. However, studies and user requirement workshops have been carried out to better determine the data transfer requirements to address e-navigation elements and facilitate development of digital communications solutions for the maritime environment.

Development of communications is not only related to the implementation strategy for e-Navigation, but is also a core element of the review and modernisation of GMDSS.

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Work on maritime communications not only looks at more effective use of existing systems, but also developments in digital communications. Some of the technologies for future digital maritime communications include:

- **NAVDAT**: this system is a development on the current NAVTEX system. The service will support the same major functions as NAVTEX, namely navigational warnings, weather forecasts and emergency information for shipping, but will provide a much greater capacity and data rate.
- **VHF Data Exchange System**: VDES, developed to meet the increasing need for data communication between maritime users and due to the significant rise in VHF data link load with the increasing use of AIS. Provides faster data transfer rates with greater integrity than current VHF data link systems.
- **Digital Selective Calling**: DSC transmits packets of data over existing maritime radio spectrum, on VHF, HF and MF. The system uses maritime mobile service identities and enables direct transmission or group / area transmissions of basic data.
- **Digital VHF** Digital VHF is the evolution of analogue based mobile radio systems currently used by mariners for voice communication, transmission / reception of distress and safety information, and reception of urgent marine information broadcasts. As well as digitally encoding voice transmissions digital VHF will enable the exchange of digital data messages.
- **Digital HF**: Digital HF is the evolution of analogue based mobile radio systems currently used by mariners for voice communication, transmission/reception of distress and safety information, and reception of urgent marine information broadcasts. As well as digitally encoding voice transmissions digital HF will enable the exchange of digital data messages.
- **Wi-Fi**: provides local area wireless data transfer using the 2.4 GHz to 5 GHz radio wave band. However, the coverage of this system is limited to within a port or harbour environment.
- **4G**: a mobile telecommunications standard supporting mobile internet broadband, succeeding 3G. Provides mobile broadband with data rates of 100s of Mbps for mobile users. Systems falling under the 4G standard include WiMAX and LTE. LTE developments include LTE-Advanced, which will provide greater range.
- **5G**: planned evolution of 4G, with data rates expected to be 1 Gbps and an intended delivery year of 2020.
- **Satellite communication systems and services including**:
    - Inmarsat Global Express – GEO satellite constellation. The latest set of services to be offered by Inmarsat including shared channel IP packet-switched internet broadband service with fast data rates provided by satellites in the K_a band with global coverage.
    - Inmarsat C – GEO satellite constellation. Existing short burst data, store and forward system providing low data rates for small message size transfers and also supporting the Global Maritime Distress and Safety Service (GMDSS).
    - Iridium – LEO satellite constellation. Existing low-earth orbiting communications, providing voice and limited internet access.

7.3 IALA Maritime Radio Communications Plan

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IALA prepared a Maritime Radio Communications Plan (MRCP) for the communications required to support e-Navigation in 2009. The MRCP has been updated in 2012 and again in 2017. The MRCP is intended to meet the key strategy element of identifying communications technology and information systems to meet user needs. This may involve the enhancement of existing systems or the development of new systems. The IALA work starts by identifying existing and future systems, then drawing on the user requirements already identified to assess the information flows and the data channels needed. VHF Data Exchange System

7.3.1 Overview

The Automatic Identification System (AIS) provides an effective means to transfer digital data. In addition to the initially intended purpose of providing vessel positional and related information in support of VTS and safety of navigation, AIS is being used for a number of other applications. This has seen an overloading of the VHF data link in some areas.

At the World Radio Conference 2015 the International Telecommunications Union identified 6 frequencies in the VHF maritime mobile band for the use of digital data transfer. The frequencies form part of the developing VHF Data Exchange System (VDES). With the ability to group these frequencies together to provide a larger band for data transfer, the VDES will enhance digital data functionality in the future.

The VHF Data Exchange System (VDES) provides a solution to ensure that the existing AIS VHF data link does not become overloaded. VDES is made possible by the development of software definable radios (SDRs) and the frequency allocation incorporates the existing AIS within the system; provides for VHF Data Exchange (VDE); and Application Specific Messages (ASM). The VDE includes an agreed Terrestrial element (VDE-T) as well as a developing Satellite element (VDE-S). The satellite component of VDES will ensure global communication capability, including the ability to access the polar regions. VDE-S is under development, with studies to be provided to the World Radio Conference in 2019. 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. VDES will include AIS as it currently exists. New techniques that provide higher throughput using multiple channels which can:

- be merged to provide higher data rates
- provide simultaneous message diversity from multiple sources.

Furthermore, VDES network protocol is optimized for data communication. The objective is that each VDES message is transmitted with a high confidence of reception.

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 and ship, ship and shore including satellite via AIS, Application Specific Messages (ASM) and VHF Data Exchange (VDE).
3. As a means of applications external to the VDES equipment itself. These applications use AIS, ASM or VDE separately or combined.

Implementation of VDES has commenced, building on the allocation of spectrum at WRC-15 where the ITU approved a standard for VDES, Recommendation ITU-R M.2092-0. A remaining outstanding issue is the approval of the satellite component for the VDE channels which is targeted for approval at WRC-19.

The system concept, including VDES functions and frequency usage are illustrated pictorially in Figure YY (full system, including Satellite allocations)

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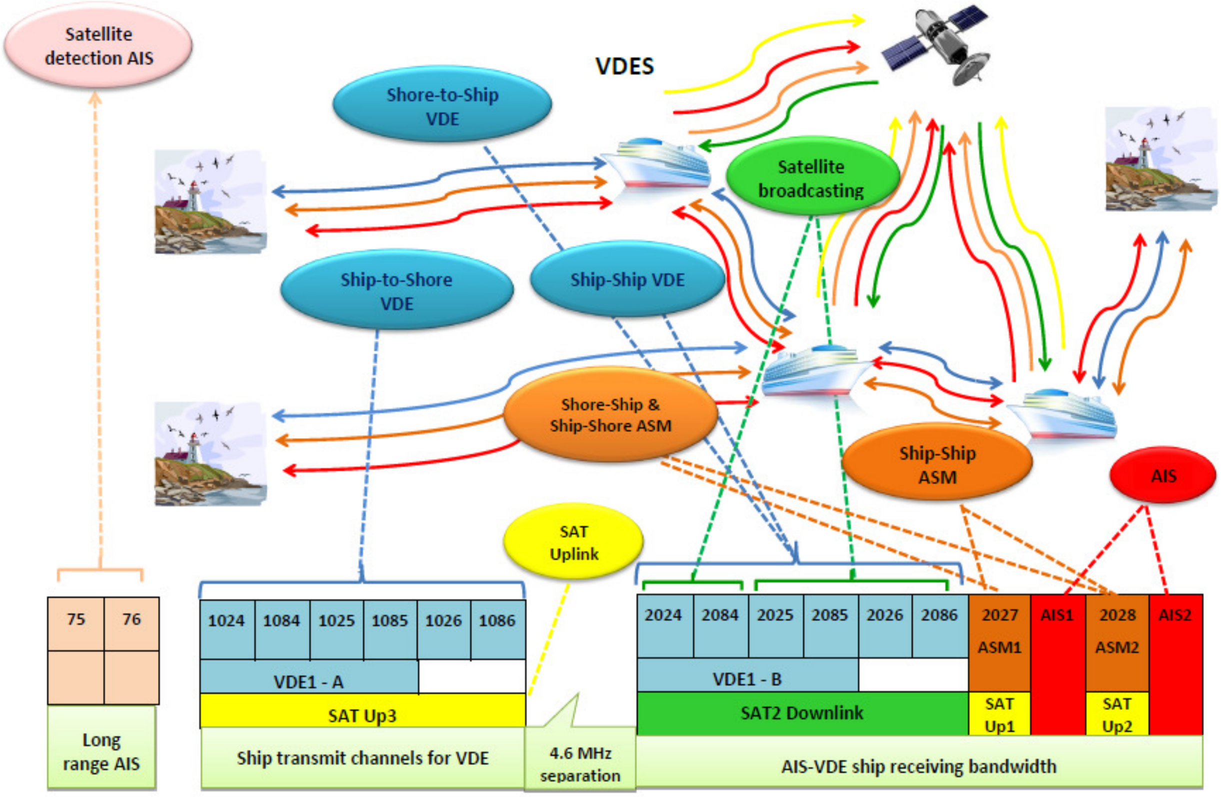

Figure YY - VDES functions and frequency use – full system

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Table XX presents the channel allocation of VDES.

Channel number in RR Appendix 18	Transmitting frequencies (MHz) for ship and coast stations	
	Ship stations (ship-to-shore) (long range AIS) Ship stations (ship-to-satellite)	Coast stations Ship stations (ship-to-ship) Satellite-to-ship
AIS 1 (87B)	161.975	161.975
AIS 2 (88B)	162.025	162.025
75 (long range AIS)	156.775 (ships are Tx only)	N/A
76 (long range AIS)	156.825 (ships are Tx only)	N/A
2027 (ASM 1)	161.950 (2027) (SAT Up1)	161.950 (2027) (SAT Up1)
2028 (ASM 2)	162.000 (2028) (SAT Up2)	162.000 (2028) (SAT Up2)
24/84/25/85 (VDE 1)	100 kHz channel (24/84/25/85, lower legs, merged) Ship-to-shore Ship-to-satellite (SAT Up 3)	100 kHz channel (24/84/25/85, upper legs, merged) Ship-to-ship, Shore-to-ship Satellite-to-ship under certain conditions (SAT2 possible extension)
24	157.200 (1024)	161.800 (2024)
84	157.225 (1084)	161.825 (2084)
25	157.250 (1025)	161.850 (2025)
85	157.275 (1085)	161.875 (2085)
26/86	50 kHz channel (26/86, lower legs, merged) VDE 2 Ship-to-satellite (SAT Up3)	50 kHz channel (26/86, upper legs, merged) Satellite-to-ship (SAT 1)
26	157.300 (1026) VDE 2, SAT Up3	161.900 (2026) (SAT 1)
86	157.325 (1086) VDE 2, SAT Up3	161.925 (2086) (SAT 1)

Table XX Channel allocation for VDES

IALA has published a Guideline that provides an overview of VDES, including the road map to develop and implement this system. [make link to IALA Guideline 1117 VDES Overview]

7.3.2 AIS

The issue of correlating a ship's identity and its position in coastal waters and port approaches has been frustrating shore authorities for some time. It has long been realised that an automatic reporting device fitted to vessels would contribute greatly to the safety of navigation and traffic management by exchanging information such as identity, position, time, course and speed between ship and shore regularly, automatically and autonomously.

Vessel Traffic Services (VTS) and ports had a requirement for clear and unambiguous identification of vessels within their area, while the ability to provide such information ship-ship was identified as a benefit for safety of navigation and collision avoidance.

Separately, the maritime community was developing the technology and rules for a VHF radio system which would enable ships to automatically communicate data with each other for the purpose of safe and efficient navigation. This was the Universal Automatic Identification System, now just known as AIS.

It quickly became clear to shore authorities that AIS also had the potential to support a wide range of maritime regulatory and traffic monitoring activities and assist with maritime security.

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- AIS is a critical element of VDES as a system. Information on AIS can be found in IALA Guideline 1082 (Overview of AIS). AIS is used by maritime authorities in a number of ways, including: search and rescue
- ship operations
- vessel tracking
- investigations and prosecutions
- environment protection
- port State control
- salvage and intervention
- compliance with pilotage requirements
- vessel traffic services
- planning of navigational services (e.g. ships' routeing measures)
- monitoring of (and use as) aids to navigation
- strategic planning

There are a number of reference documents for AIS, published by the IMO, ITU, IEC and IALA.

Reference – IALA Guideline 1084; IALA recommendation A-123, A-124, etc.

Refer to IALA publications:

- Guideline 1026 on AIS as a VTS Tool;
- .
- Guideline 1082,
- Recommendation A-123; A-124

Refer to IMO publications:

- Recommendation on Performance Standards for an Universal Shipborne Automatic Identification System (AIS) (MSC 74(69) Annex 3);
- Guidelines for the onboard operational use of shipborne Automatic Identification Systems (AIS) (Resolution A.917 (22), as amended by Resolution A.956 (23));
- Performance Standards for the presentation of navigation-related information on shipborne navigational displays (Resolution MSC.191(79);
- SN/Circ.227 Guidelines for the installation of a shipborne Automatic Identification System (amended by SN/Circ 245);
- SN/Circ.289 and 290 Guidance on the application of AIS Binary Messages;
- SN/Circ.243 Guidelines for the presentation of navigation-related symbols, terms and abbreviations
- SN/Circ.244 Guidance on the use of UN/LOCODE in the destination field of AIS messages.

Refer to ITU Publications:

- ITU-R M.1371-5 Recommendation on the Technical Characteristics for a Ship-borne Universal Automatic Identification System (AIS) Using Time Division Multiple Access in the Maritime Mobile Band;

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- Radio Regulations, Appendix S18, Table of Transmitting Frequencies in the VHF Maritime Mobile Band;
- ITU-R M.823-2 Recommendation on the technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHz in region 1 and 285-325 kHz in regions 2 and 3.

Refer to IEC Standards:

- 61993 Part 2: Class A Ship-borne equipment of the Automatic Identification System (AIS) - Operational and Performance requirements, methods of testing and required test results;
- 61108-1 (2nd edition): navigation and radiocommunication equipment and systems – Global navigation satellite systems (GNSS);
- 61162-1 (2nd edition) Maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 1: Single talker and multiple listeners;
- 62320-1: Maritime Navigation and Radiocommunication equipment and systems – Automatic Identification System. AIS base stations - Minimum operational and performance requirements - methods of test and required test results;
- 62320-2 Maritime Navigation and Radiocommunication equipment and systems – Automatic Identification System. AIS aids to navigation - Minimum operational and performance requirements - methods of test and required test result;
- 62287-2 (Part A and B) Class B AIS (Part A – CSTDMA; Part B – SOTDMA);
- 61097-14 (pending) Global Maritime Distress and Safety System (GMDSS). AIS search and rescue transmitter (AIS-SART) – Operational and performance requirements: methods of testing and required test results.

7.3.2.1 Satellite AIS

Terrestrial AIS systems have the benefit of continuous coverage and detection rates that approach 100% close-in to shore. Terrestrial AIS includes both receive and transmit capabilities, although many shore stations (AIS base stations) may be receive only. Terrestrial AIS have the disadvantage of very limited range and high cost per square mile covered.

Satellite AIS (S-AIS) is a receive only system, but has the advantage of providing complete global coverage with comparable average detection performance as well as low cost per square mile covered. It has the disadvantages of lower detection rates close to shore stations and only periodic vessel refresh.

Satellites carrying AIS units are placed in Low Earth Orbit (LEO) where they travel at about 27,400 km/h at a distance of 650km to 800km from the surface of the earth. A single revolution around the earth takes approximately 90 minutes as these LEO satellites are not geostationary, therefore a constellation of satellites is required to provide coverage in a timely method.

S-AIS and terrestrial systems each provide capabilities offering unique and complementary benefits to national administrations, which mean that both are needed for complete maritime domain awareness.

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7.3.2.2 ASM and VDE channels

VHF data exchange refers to the exchange of data in a digital manner on specified frequencies within VDES. The ITU identified 6 frequencies for VDE and 2 frequencies for ASM use.

The 2 ASM frequencies were identified specifically to provide increased capability for the transmission of application specific messages. Within the terrestrial environment, ASM can be both transmitted and received. ASM can also be received by satellite, similar to the reception of AIS by Satellite.

The VDE frequencies were agreed to address the ongoing requirement for digital data exchange as identified in e-Navigation. The ability to group frequencies together within VDES will provide for increased bandwidth within the VDE aspect of VDES. The frequencies allocated to VDE can be used individually (as 25 kHz channels) or grouped together to provide 50 kHz or 100 kHz. The increased bandwidth, coupled with revised approaches to access the bandwidth, will support increases in data transfer when compare with existing AIS. Following ITU-WRC2015 the VDE frequencies were agreed for transmit and receive at the terrestrial level, while work is continuing to enable satellite use of the frequencies to enable a truly global digital data exchange capability.

7.4 Digital VHF and HF

VHF is commonly used worldwide in maritime for general voice communication, transmission/reception of distress and safety information, and reception of urgent marine information broadcasts, nominally for ‘line of sight’ distances. VHF is traditionally based on analogue technologies. Changing user requirements and a demand for more sophisticated services have led to the development of digital mobile radio standards and systems.

Digital VHF should enable full communications – duplex and simplex – with higher data rates and more efficient use of spectrum. Noting the nominal ‘line of sight’ aspect of VHF, digital VHF should improve on the current operational ranges for quality voice communications, while enabling digital data to be transmitted.

7.4.1 Digital Selective Calling (DSC) (VHF and HF)

DSC is a tone signalling system, which sends packets of digital data over radio spectrum. The MF/HF DSC distress and safety channels are 2187.5, 4207.5, 6312.0, 8414.5, 12577.0, and 16804.5 (kHz); the VHF DSC distress and safety channel is channel 70.

DSC is similar to the tone dialling on a telephone, but with the ability to include data such as the vessel’s identification number, the purpose of the call, the vessel’s position, and the channel for further voice communications. With DSC there is the ability to call individual vessels directly by use of their MMSIs (rather like a telephone number) or send a signal to vessels in the area – for example when sending a Distress/Urgency call.

Table 1 presents the key characteristics of DSC. [1]

System	Frequency	Bandwidth	Data Rate
DSC	22187.5, 4207.5, 6312.0, 8414.5, 12577.0, and 16804.5 (kHz) 156.525 MHz	VHF – 25 kHz HF – bandwidth constrained by SSB modulation scheme	VHF – 1,200 bps[2] HF – 300 bps

1 ITU Recommendation ITU-R M.493-12

2 For VHF DSC special cases bandwidth channels may be adjusted (12.5 Khz) or modulation scheme may enable data up to 9,600 bps (ITU Recommendation ITU-R M.1084-4)

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Table 1: DSC characteristics

7.4.2 Digital VHF and HF Radio (other than DSC)

HF is commonly used worldwide in maritime for general voice communication, transmission/reception of distress and safety information, and reception of urgent marine information broadcasts. Long-range HF communications rely on refraction of signals by the ionosphere. HF can have a range of between 50 – 300 kms, with long-range HF reaching to 4,000 kms. The greater range depends on antenna configuration, power levels and atmospheric conditions.

Other than digital selective calling (DSC – section 3.1.6 refers), HF is based on analogue technologies. Changing user requirements and a demand for more sophisticated services have led to the development of digital mobile radio standards and systems. Digital techniques for HF, including digital voice, have been developed to address the inherent weaknesses of HF such as susceptibility to interference, fading and dropouts due to ionospheric effects and frequent poor voice quality.

Digital HF systems should enable full duplex communications, higher data rates and more efficient use of spectrum while maintaining or improving on the current operational ranges for high quality voice.

The key characteristic of digital VHF or HF relates to changes in the over-the-air protocol rather than making fundamental changes in the architecture of existing VHF and HF mobile radio networks. In Europe, there is a new European Standard for Digital Mobile Radio (DMR). The DMR operates within the existing 12.5 kHz channel spacing achieving two channels through two-slot TDMA. Voice transmissions are encoded using the AMBE+2 codec[3]. Features that can be supported include fast call set-up, calls to groups (multicast) and individuals (unicast), and short data and packet data calls.

The communications modes include individual calls, group calls and broadcast calls. Other important DMR functions include emergency calls, priority calls, full duplex communications, short data messages and IP-packet data transmissions.

Table 2 provides the technical characteristics for digital VHF/HF.

System	Frequency	Bandwidth for a simplex channel	Data Rate
Digital VHF/HF	136-174, 400-470, 450-520 MHz	6.25 kHz	4.8 kbps

Table 2: Digital VHF/HF system characteristics

7.5 Wi-Fi

The Wi-Fi communication system is one that runs across local networks, and is defined by the Institute of Electrical and Electronic Engineers (IEEE)[4] Wi-Fi networks consist of routers and adapters which translate a wired Ethernet connection into a local wireless network for devices to connect. Wi-Fi provides internet access to users. Wi-Fi hot spots may be set up in public places, such as ports, airports and restaurants to enable users to access the internet whilst on the move. Wi-Fi networks may be set up on board a vessel to enable data transfer within the ship, but access to internet is reliant on access through a service provider.

Table 3 presents the key characteristics of Wi-Fi.

System	Frequency	Bandwidth	Data Rate
Wi-Fi 802.11ac	5 GHz	40 MHz	Up to 1.3 Gbps

Table 3: Wi-Fi system characteristics

3 AMBE +2 codec is a current version of vocoder - voice encoder/decoder. The vocoder is the function within a digital radio that converts an analogue speech signal into a digital bit stream.

4 IEEE standards 802.11 – a set of specifications for wireless local area networks (WLAN).

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The IEEE 802.11ac standard is a recent standard introduced which is solely based on the 5 GHz band and is able to theoretically transfer data at rates up to 1.3 Gbps. The higher frequency 5 MHz channels have a lower range than the lower frequency 2.4 MHz channels, however 2.4 MHz is a very congested band and is likely to experience interference.

7.6 4G and 5G networks

4G is the 4th generation of mobile telecommunications, succeeding the 3rd generation system, 3G. 4G is defined as a set of standards to provide a given level service for a communication system. Within these standards, various technologies are built, which can then be identified as 4G if they met the required standards.

Two systems that are considered to meet this standard are WiMax and LTE. WiMax was initially invested in heavily, with the technology offering high speed internet connection within a large coverage areas. However, the uptake of WiMax has been limited leading a major provider, Sprint, to decommission networks in some countries. In contrast, LTE (long term evolution) is widely used, with the more recent development, LTE-Advanced, regarded as a fully compliant 4G network.

4G is defined by the set of IEEE standards and LTE-Advanced is a technology that complies with these standards. The LTE-Advanced network uses Orthogonal Frequency-Division Multiplexing (OFDM), by encoding data on multiple frequencies.

Table 4 presents the key characteristics of LTE-Advanced.

System	Frequency	Bandwidth	Data Rate
4G – LTE Advanced	2.6 GHz	20 MHz	600 Mbps (download)

Table 4: 4G system characteristics

5G is a development from the 4G network and is advertised to be delivered from 2020. This latest development includes faster mobile data rates. The updated standards that will define the 5G network are still under consideration, but network trials have been successfully implemented. In bench trials speeds with a peak bitrate of 1 Tbps have been achieved. It is anticipated that realistic rates for 5G will achieve 1.2 Gbps.

5G developments will ensure a much faster connection than 4G. Not only will the data rate be increased, but the capacity is also intended to increase allowing for more users to access the higher speeds simultaneously.

Table 5 provides the technical characteristics for 5G.

System	Frequency	Bandwidth	Data Rate
5G	SHF – above 6 GHz	Greater than 4G	1.2 Gbps (download)

Table 5: 5G system characteristics

7.7 Satellite communication systems and services

There is a wide range of satellite services that are currently provided, with plans for new services to be introduced in the near future. Satellite, in itself, is not a communications technology, rather the satellite carries a payload for communications and uses spectrum that is allocated by altitude. Satellite services are provided from geostationary (GEO) satellites, medium earth orbit (MEO) and low earth orbiting (LEO) satellites.

GEO satellites operate at an altitude of 35,786 km in orbit over the Equator (0 degrees latitude) at various longitudes. These satellites have an orbital period equal to the rotation of the Earth and appear stationary above a fixed point on the Earth's Equator. These satellites provide continuous coverage for

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the majority of the earth's surface, but do not provide coverage in the polar-regions (e.g. at latitudes typically greater than 70°).

MEO satellites operate at altitudes between 2,000 – 35,786 km. The most common MEO orbits are at just over 20,000 km with an orbital period 12 hours. These satellites are commonly used for navigation services. MEO have recently been introduced to support search and rescue (MEOSAR).

LEO satellites operate at altitudes between 80 – 2,000 km. The majority of LEO satellites make a complete revolution of the Earth in approximately 90 minutes. For persistent coverage of any one area of the Earth there is a need to have a grouping of multiple satellites, known as a 'constellation'. The footprint of a LEO satellite would be in the realm of 3,281 km or 1,770 nautical miles. These satellites use different orbiting planes and can provide full global coverage, but coverage is reliant on the orbit of the satellite and no one spot on the Earth's surface can be served continuously by a single satellite.

Inmarsat is an example of a GEO satellite constellation. Inmarsat was originally established on the initiative of the International Maritime Organization (IMO) to operate a satellite communications network for the maritime community including public safety services. Current data services include support for GMDSS; high data rate internet broadband/data streaming; low data rate, low latency, high availability data reporting; short burst data, store and forward.

Iridium is an example of a LEO satellite constellation. Iridium uses a constellation of over 60 cross-linked LEO satellites to provide high-quality voice and data connections, including coverage over polar regions with the use of polar orbiting satellites.

Some sample GEO and LEO satellite options are presented. As satellite technology is developing rapidly, this is not an exhaustive representation but provides a general overview of the existing, and expected, capabilities to address maritime requirements.

7.7.1 Geostationary satellites (GEO)

Noting that the satellite itself is the means to deploy a specific payload for communications, there are a number of existing or developing technologies that can be deployed on GEO satellites.

7.7.1.1 Inmarsat C

Inmarsat C is a store and forward satellite service used to transmit data from shore-ship, ship-ship and ship-shore. It provides global coverage and is design to send low data packages such as position reports, meteorological reports and navigational warnings. The benefits of this technology include the restriction to maritime services, reducing the load on the system.

The Inmarsat C is used for low data transmissions. The data rate provided by the Inmarsat C service is 600 bps and works in the L band.

Table 6 provides the technical characteristics for Inmarsat C.

System	Frequency	Bandwidth	Data Rate
Inmarsat C	1626.5-1645.5 MHz (transmit) 1530.0- 1545.0 MHz (receive)	15-20 MHz	600 bps

Table 6: Inmarsat C technical characteristics

Inmarsat Global Express (GX) is the latest satellite service offering from Inmarsat providing higher bandwidth than the existing Inmarsat SwiftBroadband and FleetBroadband services. A global service, it provides broadband access to vessels outside the reach of normal terrestrial broadband, such as 4G and 5G. With the Ku band becoming increasingly saturated, the Inmarsat GX system has migrated the broadband services to the Ka band. Although the Ka band is more susceptible to rain attenuation, it provides the capacity that is required for delivering a high bandwidth internet connection. The service uses a number of spot beams, giving a high data rate to a wider area, with further steerable beams also

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available to provide additional capacity where it's needed. However, this service is not reserved solely for maritime meaning there is a higher risk of interference.

The Inmarsat GX system functions in the SHF-EHF frequency bands (26.5-40 GHz) and provides higher bandwidth for internet connection. The service is expected to facilitate a data rate of 50 Mbps.

Table 7 provides the technical characteristics of Inmarsat GX.

System	Frequency	Bandwidth	Data Rate
Inmarsat GX	26.5-40 GHz	64 MHz per spot beam 200 MHz for high capacity overlay	50 Mbps

Table 7: Inmarsat Global Express system characteristics

7.7.2 Low Earth Orbiting satellites (LEO)

Noting that the satellite itself is the means to deploy a specific payload for communications, there are a number of existing or developing technologies that can be deployed on LEO satellites.

7.7.2.1 Iridium

Iridium has been effectively providing satellite communication services since 2001. While the initial service was seen as effective for rescue services and missions to remote areas of the globe, the demand for services has led to the development of Iridium Next. The revised basic functions include additional bandwidth, end to end IP technology and the incorporation of earth imaging and other secondary payloads.

The Iridium satellite system uses L band transponders to communicate with the ground based users with frequencies in the band 1616 - 1626.5 MHz providing up to 134 kbps bidirectional (OpenPort broadband service)

Table 8 provides the technical characteristics of Iridium (Pilot).

System	Frequency	Bandwidth	Data Rate
Iridium (Pilot)	Ground users - 1616 – 1626.5 MHz (L-band) Terrestrial gateway 29.1 – 29.3 GHz	31.5 kHz	Up to 134 kbps

Table 8: Iridium (Pilot) system characteristics

The differences in the technologies are not only related to area of coverage and data rate, but also to the transmission process – for example, some are addressed (point to point only), while others can be addressed, broadcast to a group of ships or broadcast to a geographic area.

7.8 Overview of Digital Communications Systems

Table 9 provides a summary matrix outlining the communication technologies.

Communication Technology	Data rate	Infrastructure	Coverage	Transmission	Maritime / public
NAVDAT	12-18 kbps	Based on NAVTEX	250/300NM	Broadcast	Maritime
VDES VDE	307 kbps	VHF Data link, RR Appendix 18 channels	Line of sight, approx 15NM-65NM Satellite component provides further coverage	Addressed / broadcast	Maritime

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Communication Technology	Data rate	Infrastructure	Coverage	Transmission	Maritime / public
VDES ASM	9.6 kbps	VHF Data link, RR Appendix 18 channels	Line of sight, approx 15NM-65NM	Addressed / broadcast	Maritime
Wi-Fi (IEEE 802.11ac)	1,300 kbps	Routers/Access points	50m	Addressed	Public
Digital VHF	4.8 kbps	Base station/mobile radios	Line of sight, approx 15NM-65NM	Addressed	Maritime
Digital HF				Addressed	
4G (including LTE)	600 Mbps	4G Base stations	5-30km	Addressed	Public
5G	1,200 Mbps	5G base stations	5-30km	Addressed	Public
GEO Satellite					
Inmarsat C	600 bps	Satellite service	Global, spot beams	Addressed / broadcast	Maritime
Inmarsat GX	50 Mbps	Satellite functioning on Ka band	Global, spot beams	Addressed / broadcast	Cross Industry
LEO Satellite					
Iridium	Up to 134 kbps	Satellite functioning on L band	Global	Addressed / broadcast	Cross Industry (Iridium Pilot Maritime)

Table 9: Summary of communication technologies

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