MARITIME COMMUNICATIONS – IDENTIFYING CURRENT AND FUTURE SATELLITE REQUIREMENTS & TECHNOLOGIES

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Abstract

It is tricky to predict the future, especially in the maritime communications market – what are the future demands? Which technologies will be available? How will the regulatory bodies think in the future? Within this paper, the recent development towards future satellite requirements and technologies will be spotlighted. Four use case scenarios are in the focus here, namely: e-navigation, Arctic communications, autonomous ships, and evolution of GMDSS.

1. Introduction

Maritime communications will experience major changes during the next two decades. Not only will the evolution of e-Navigation require higher digital data exchange capacities, but new connectivity solutions for the crew will also increase bandwidth needs. New potential digital VHF services are envisioned [1] while other innovative digital VHF implementations are also in the pipeline. These are only some examples of emerging trends, technologies or demands.

Many initiatives are currently on-going within different organizations, such as IMO's 'e-Navigation Strategy' [2] and the IALA Maritime Radio Communication Plan [3], with the ultimate overall goal of modernizing statutory maritime communications systems with an increased reliance on robust communications, including satellite communications. In addition, upcoming commercial satellite systems such as Inmarsat Global Xpress, O3b, Telenor THOR 7 in Ka-Band and Iridium NEXT in L-Band are expected to increase competitiveness, reduce the cost per bit and pave the way for new broadband services that will complement legacy narrowband offerings.

Current research activities and results in the area of the maritime satellite market will be evaluated and described in detail in this paper. These evaluations show that the maritime user applications requiring access to communication systems can be divided into the following main areas: Safety & Security; Vessel operations; Regulations/Policy; Tracking & Monitoring; Crew Welfare; Shared Situational Awareness. Furthermore, the paper will investigate new opportunities for satellite systems, services and technologies addressing the maritime communications demands in 2020. Here, four use case scenarios are identified and selected:

e-Navigation: Potential user requirements that might be achievable with a satellite service in a future e-navigation scenario and their expected impact on existing architectures will be described.

Arctic communications: The Arctic is a new and relatively unexplored area for the future statutory and commercial maritime communications market. With the limited availability of other communications options at sea, satellites will play a major. Possible future high level architectures are investigated towards their advantages and challenges.

Autonomous Ships: Unmanned merchant ships on intercontinental voyages are an attractive future application as the world is facing a shortage of seafaring personnel while the number of ships is growing. For unmanned operation the ship will need to be equipped with advanced sensor systems to detect and avoid obstacles, a positioning and navigation system to determine and control exact location, speed and course as well as route, and the engine also requires advanced on board control systems to operate the ship and its equipment. There will be a need for communications technology that will enable wireless monitoring and control functions both on and off board. A reliable communication link with robust communication architecture might be achievable with a satellite service in a future autonomous ship scenario.

Evolution of GMDSS: The Global Maritime Distress and Safety System (GMDSS) [4] is the radio system whose techniques and frequencies are defined by the ITU and for which mandatory equipment carriage requirements has been adopted by the IMO for commercial vessels. There is currently a project within the IMO to review and modernize the GMDSS in the period 2012-2017.

2. Identification and Selection of Use Case Scenarios

Relevant to the future of satellite communication for maritime nine key requirements were derived:

Tracking/Monitoring: this requirement applies to vessels but also goods/oil/persons on-board the vessel. It is expected that from a technological perspective type of requirements would principally need capacity on the Return Link (from vessel to ground).

On Route information update: this requirement covers for example destination updates, waypoint and route optimization, maps update, weather information, ice information, or currents information. From a technological perspective it is expected that it principally requires a Forward Link capacity (from ground to vessel).

Remote Control of vessels: this requirement is mainly used in the scenario of unmanned vessels, but also as a help to the crew for monitoring and decision making. Remote Vessel Control requires bidirectional links. From a bandwidth perspective it is expected that significant capacity would be required mainly on the Return link (such as video, and audio and eventually data from vessel to ground).

Safety and Security system/alerts: This requirement applies to voice and data communication, alerting, positioning information. Return link with high priority, availability and low latency is required for this purpose.

Worldwide available communication for vessels: It is expected that global coverage might be needed in areas where limited communication coverage is available. This is particularly applicable to the in the Arctic region.

Crew/Entertainment communication: cargo and passenger ships require communication access for entertainment purposes. High bandwidth capacity is needed in both directions.

Share of info among vessels during route/after route: this could apply among vessels of the same company, be open to partner’s company or all ships.

Communication for under building sea platforms/ sea power plants: the application are relevant to wind, underwater turbines, others.). These are quasi static vessels for which High Altitude Platforms may apply.

Regulations and Policies: Today all the currently required systems as GMDSS, LRIT, AIS, etc. are being regulated. It is expected that regulatory bodies will remain key players in the definition of next generation services.

After capturing the set of high level requirements, they have been grouped in user scenario as in Table 1. This justifies the 4 user cases further investigated in this paper.

Table 1: Set of high level requirements.

	E-Nav	Arctic Comms	Autonomous Ships	Evolution of GMDSS
1 Tacking / Monitoring	X	X	X	X
2 On route information update	X		X	X
3 Remote control of vessels			X	
4 Safety and security systems / alerts	X	X	X	X
5 Worldwide available communications for vessels		X	X	
6 Crew/Entertainment communication	X	X		
7 Share of info among vessels during route / after route	X	X	X	X
8 Communication for under building sea platforms		X		
9 Regulation and policies			X	X

3. E-Navigation

E-navigation is an IMO project that is underway and looking at a future digital concept for the maritime sector. Work to date has identified possible future developments in:

- improved, harmonized and user-friendly bridge design with improved reliability, resilience and integrity of bridge equipment and navigation information together with integration and presentation of information in graphical displays such as that received via communication equipment;
- improved reliability and resilience of on-board Position, Navigation and Timing (PNT) systems;
- improved shore-based services with means for standardized and automated ship-to-shore reporting, improved access to relevant information for Search and Rescue (SAR), and improved communication of VTS (vessel traffic system) information.

At the present time IMO is developing a strategy implementation plan to set up objectives and specific timelines for e-navigation for the period 2015-2019. The plan will be based on, where possible, the existing navigation and communication equipment and systems.

An investigation on the role of digital communication technologies in e-Navigation has been performed in [5], comprising a fairly comprehensive overview of possible e-Navigation services. These services are characterized by message frequency and size for different traffic scenarios; open sea (OS), coast (Co), and port (PA). This is done with the presumption that limited bandwidth is available and that only "necessary" communication needs to be included (i.e. live video and similar bandwidth-hungry services are not included). The services are group in seven categories and are then mapped onto six data carrier classes (Figure 1), and traffic demands in each carrier class are estimated.

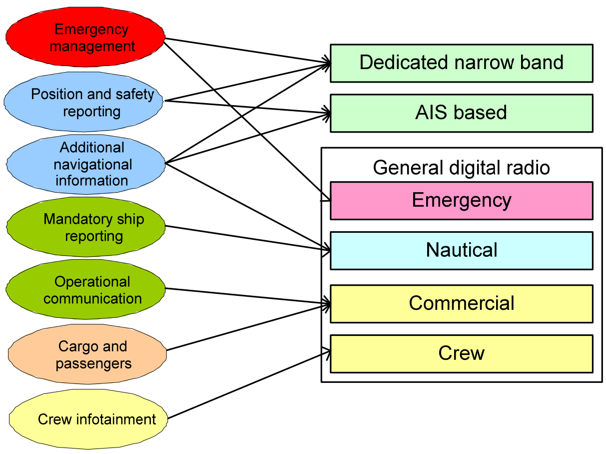

Figure 1: Mapping of e-Navigation services onto data carriers.

Some conclusions that can be drawn from this method of approach are:

- Automated Information System (AIS) [6] capacity is fairly close to maximum utilization, at least in congested waters, and should be reserved for real-time navigation data. There are limited possibilities to add more data to this carrier, unless new frequencies are allocated.
- Purely navigational related services (excluding VTS image and electronic navigational chart (ENC) updates) could in principle be serviced by adding four to five channels for AIS type transmissions (about 30 kbps). However, this could also be done by two standard digital VHF channels.
- Capacity demands are much higher near coast and in port than at open sea. Thus, a shore-based communication infrastructure can most conveniently be used to cover coast and port approaches, and by that complement satellite systems, which in any case are required at open sea.
- A total cumulative bandwidth of around 200 kbps should be sufficient to cover all relevant e-Navigation services, even in very busy ports. If VTS image and ENC updates are kept out, it should be sufficient with 100 kbps even when some (narrow-band) crew infotainment services are included.

3.1. Requirements for e-navigation evolution

Potential user requirements that might be achievable with a satellite service in a future e-navigation scenario are described in the following.

First, improved access to navigational safety information is needed. At the moment Maritime Safety Information (MSI) which comprises navigational warnings, meteorological warnings and forecasts, and search and rescue (SAR) information, is promulgated by MSI providers via NAVTEX and Enhanced Group Call (EGC) systems (EGC is a part of the Inmarsat C system and supports two broadcast services: SafetyNET and FleetNET). The information is in text (ASCII) format only and is displayed on the receiver's screen and can be printed on the dedicated printer. Developments in the interfacing of bridge systems are expected to display this information in an increasingly centralized way, e.g., automatically routed to navigation displays (ECDIS and radar screen).

However, the information is not specific to a particular ship or voyage but to a defined area. EGC information for instance will be addressed to one of the 21 NAVAREAs or METAREAs into which the world is divided.

Navigational information of a more routine nature comprising Notices to Mariners, Electronic Navigation Chart updates and corrections to all nautical publications is typically distributed via post and collected when the ship goes into a port. This can put the ship at risk if it is caused to sail in waters for which the nautical charts are not up to date.

It is expected that ever more navigational information will be made available to assist ships in safe navigation, collectively referred to as Maritime Service Portfolios (MSP). This comprises information such as VTS, Navigation Assistance, Traffic Organization, Local Port Service, Pilotage, Tugs, and Maritime Assistance Services which will be made available by relevant shore authorities. Therefore, new user requirements arising from this are:

- Maritime Safety Information (MSI) received by a ship should be applicable to the ship's specific voyage.
- Notices to Mariners, ENC updates and corrections to nautical publications should be received electronically without delay in delivery.
- Specific services providing information to specific regions (e.g. Maritime Service Portfolios) should be mapped to those regions with status and access requirements.

Second, integration of communication infrastructure is needed. e-Navigation will need data communications capacity and technical characteristics that support the harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment.

The currently available communications infrastructure includes systems with different ranges, bandwidth etc. which have different uses. Short range systems include VHF, 4G and 5G and long range HF and satellite systems (across various frequency bands). New systems are likely to be developed (for example, maritime cloud) for future use. For the future seamless integration of all available communications infrastructures will assist users with how they can be used and with future systems being developed. Therefore, new user requirements arising from this are:

- Provide harmonized on-board integration of navigation systems and displays.
- Harmonize Integration of all communication infrastructures with satellite infrastructures when in High Seas, Coastal Approach or Polar regions (when no other means of communication are available).

Third, low cost communication services are needed. In many parts of the world it is becoming increasingly difficult to recruit seafarers to work as crew on ships. Life at sea is not considered to be an attractive career in part due to the loneliness of the life. Crews are demanding the means to keep in touch with their families and friends and join in the types of entertainment services they would use at home.

A wide variety of services are available for supplying entertainment to ships. Receive only satellite television is available for free to view and pay television channels. Wi-Fi can be made available on the ship so that it is possible for crew to use their personal laptop, smartphone or tablet to send and receive a call directly, send and receive SMS and MMS and obtain Internet access. Internet connection is available particularly from VSAT suppliers and from terrestrial suppliers in coastal areas. Services providing roaming from satellite to terrestrial communication are available.

Cost of services is however a concern for crew use and few services offer enough bandwidth for streaming. Therefore, a new user requirement arising from this is:

- On-board low cost communication services available to crews which will also allow them to access streaming data such music, video, radio podcast or specific applications via WiFi on-board the vessel. Differential billing per on-bard users is required. Priority and pre-emption capabilities should be available in order to combine navigation and commercial services within the same User terminal infrastructure.

Fourth, low cost data VHF services are needed. All ships which are equipped with radio equipment carry a VHF radio working on the maritime mobile channels and increasingly ships are equipping with AIS which also works in the VHF band. The VHF radio provides voice communication and the AIS provides information about surrounding ships and has a limited ability to send and receive short messages.

Other data services however require additional equipment such as NAVTEX receivers working at 518 kHz for maritime safety information and satellite terminals which can provide maritime safety information and data exchange by e-mail.

A VHF data service would therefore be an attractive option for many users. Whilst provision of coast based terrestrial VHF data services can be envisioned the economics of their provision may not be attractive in many parts of the world. A wide area service provided by satellite however might be attractive. Therefore, a new user requirement arising from this is:

- A satellite based data exchange system which can use the commonly carried VHF equipment on the ship. These equipment would therefore use the terrestrial VHF network when available or satellite VHF network out of terrestrial coverage

The major impact on the existing architecture is expected to be related to integration of all communication infrastructures with satellite infrastructures.

4. Arctic Communications

The Arctic comprises the latitudes above 60°N except for the area of sea between southern Greenland and northern Norway which is warmed by the Gulf Stream and remains ice free. The Arctic is currently experiencing a warmer climate which is slowly reducing the permanent ice cover and making more of the area accessible to shipping. Fishing fleets, cruise ships and cargo ships are operating above 80°N and oil/gas exploration is extending above 75°N. There are theoretically two passages for shipping to cross the Arctic, the Northern Sea Route along the Russian coast and the Northwest Passage along the Canadian coast. Both have political difficulties as the respective countries claim them as territorial waters and not international straits. Of the two, the Northern Sea Route (NSR) is the more practical for navigation, and a minor number of ships transit NSR each year.

Communication using geostationary satellites is theoretically possible up to 81°N, which is 0° elevation, but the practical limit is typically assumed to be around 76°N. Inmarsat satellites serve the Arctic up to 76°N except for an area around 120°E of the Laptev Sea Russia and around 120°W of the Beaufort Sea Canada. The polar orbiting satellites of Iridium and Cospas-Sarsat serve the whole of the Arctic, and HEO orbiting satellites are under consideration. IMO has procedures in place to possibly recognize satellite systems in addition to the systems provided by Inmarsat and Cospas-Sarsat.

Commercial ships visiting the Arctic need to comply with the GMDSS requirements of the SOLAS Convention, which requires them to be fit for Sea Area A4 when sailing above 76°N, necessitating an HF installation for distress alerting, communications and reception of Maritime Safety Information.

The IMO is currently drafting a Polar Code intended to become mandatory, comprising among others requirements for communications and information exchange additional to the normal SOLAS requirements.

4.1. Requirements for Arctic communications

Potential user requirements that might be achievable with a satellite service in a future Arctic scenario are described in the following. First, distress and safety communication infrastructure is needed. The traditional HF radio equipment carried by ships in Sea Area A4 relies on HF shore stations being available which can handle distress alerts and traffic and safety communications. The number of stations in the world which can fulfil these roles is diminishing. There are also a diminishing number of skilled operators who can work HF circuits and other operators find the circuits to be unstable.

The Arctic is significantly less well equipped with safety infrastructure than other parts of the world. There is a lack of facilities and shore settlements are remote. Reaction to an incident however needs to be timely as survival times are limited because of the cold climate.

The Polar Code includes a requirement for two-way voice and data communications ship/shore, shore/ship at all points along the intended operating routes. This will not be achievable using HF circuits which will not have 24 hour continuous availability. Therefore, a new user requirement arising from this is:

- An alternative system to HF communications which can be adopted by the IMO and which can provide timely distress and safety communication functions for latitudes above 76°N.

Second, maritime safety information is needed. Ships operating in Sea Area A4 rely on HF narrow band direct printing for the reception of MSI. The number of shore stations providing this service is diminishing and the available information is limited. The Polar Code, in addition to the GMDSS requirement for ships to have the means for receiving forecasts of the environmental conditions, has some extra requirements concerning ice information: Ships shall have the means to receive up-to-date information including ice information for safe navigation; Ships shall have the means of receiving and displaying information on ice (thickness and concentration); Ships shall have the means to receive current information on the extent and type of ice and icebergs in the vicinity of the intended route.

Developments within the IMO e-navigation project are further leading to a requirement for MSI received by a ship to be applicable to the ship’s specific voyage. Therefore, a new user requirement arising from this is:

- A new MSI service which can be received by ships sailing above 76°N and can additionally provide ice information.

Third, reliable communications in the Arctic Region is needed. Ships operating in Sea Area A4 require reliable two-way voice and data communications with the shore for exchanging information relating to the needs of the ship, its crew and passengers. The Polar Code specifically requires suitable means of communication to enable telemedical assistance in polar areas to be provided and suitable means of communication for contacting emergency response providers for salvage, SAR, spill response, etc. to be provided. Cruise ships are likely to need systems with data rates of 25 Mbps, and oil and gas exploration vessels data rates up to 300 Mbps. This is definitely unachievable using HF circuits, which are limited in capacity to at most 10-20 kbps. Therefore, a new user requirement arising from this is:

- Communications circuits providing reliable communication capability for ships sailing above 76°N and capable of multi-Mbps data rates.

5. Autonomous Ships

An autonomous vehicle is a vehicle that is capable of functioning on its own. It may be manned or unmanned or it may be remotely controlled from a manned station. Unmanned vehicles have been successfully used in space and on railways for many years. Unmanned aircraft are increasingly being used and unmanned underwater craft are in service. Currently foreseen applications for an unmanned ship are for routine inspection and maintenance in the oil gas and wind farm industries, monitoring and data collection for marine and weather science and research, environmental monitoring, and support for law enforcement and search and rescue. These applications will involve relatively small crafts operating over relatively short distances. Unmanned merchant ships on intercontinental voyages are an attractive future application as the world is facing a shortage of seafaring personnel while the number of ships is growing. Seafaring is not now an attractive career for young people due to the remoteness of the work. The current trend towards slow steaming to reduce fuel costs leads to longer voyages which further reinforces the unattractiveness for the seafarer. Moreover crew costs, at more than 40%, account for a major share of ship operation costs. For unmanned operation the ship will need to be equipped with advanced sensor systems to detect and avoid obstacles, a positioning and navigation system to determine and control exact location, speed and course as well as route, and the engine also requires advanced on board control systems to operate the ship and its equipment. There will be a need for communications technology that will enable wireless monitoring and control functions both on and off board. A reliable communication link with a robust communication architecture might be achievable with a satellite service in a future autonomous ship scenario.

5.1. Requirements for autonomous ships

Potential user requirements that might be achievable with a satellite service in a future autonomous ships scenario are described in the following. First, infrastructure towards remote operations is needed. Under normal autonomous operation the requirement will be for a shore control center to monitor the ship status and the communications will be periodic updates ship to shore. To handle known events the requirement will be for the shore control center to ensure safe operation by acknowledging decisions if required and the communications will be event based data exchange.

In a special situation the requirement will be for a shore control center to directly operate the ship by remote control and the communications will be a direct link. Therefore, new user requirements arising from this are:

- Secure communications in order to prevent the ship being hijacked by other parties.
- High availability so that any special situations can be handled in a timely manner.
- Latency of less than one second so that the ship can be remotely controlled in real time.
- Bandwidth of up to 4 Mbps so that radar and video pictures can be sent to the shore.
- Redundancy of the equipment on board the ship with fail to safe procedures in case of equipment failure.

Second, the reliability and resilience have to be improved for on-board Position, Navigation and Timing (PNT) systems. It is unlikely that the positioning and navigation system for an autonomous ship will be able to rely solely on the use of Global Navigation Satellite Systems (GNSS) for PNT. A requirement for autonomous ship operation can be the use of two GNSS, e.g. GPS and Galileo, such that in case of failure of one of the two systems the ship can be still operated autonomously. However, although there are multiple systems available (GPS, GLONASS, Galileo, Beidou etc.), all the systems operate with low powers in the same frequency band. They are thus all susceptible to ionospheric disturbances and radio interference, either from spurious signals or deliberate jamming. Therefore, a new user requirements arising from this is:

- Improving the ability of the PNT system to detect and compensate external and internal sources of disturbances, malfunction and breakdowns in parts of the system.

6. GMDSS Evolution

The Global Maritime Distress and Safety System (GMDSS) is the radio system whose techniques and frequencies are defined by the ITU and for which mandatory equipment carriage requirements has been adopted by the IMO for commercial vessels. There is currently a project within the IMO to review and modernize the GMDSS in the period 2012-2017. To date, a high level review has been completed which has concluded that the functional requirements of the GMDSS are still appropriate. The project is currently conducting a detailed review addressing issues including: the evolution of Maritime Safety Information (MSI) broadcast systems; problems which might arise due to lack of HF stations in the future; future definitions of Sea Area A3 (currently within geostationary satellite footprint) and Sea Area A4 (currently outside geostationary satellite footprint); integral use of voice communications; improved shore to shore communications between Rescue Coordination Centers.

The final phase will be a modernization plan. One change that has occurred since the inception of the GMDSS in the 1970s is that radio equipment is now a consumer commodity and there will likely be many other radio systems on a ship besides the GMDSS. These may have a role to play in distress and safety in the future.

6.1. Requirements for GMDSS evolution

Potential user requirements that might be achievable with a satellite service in a future GMDSS scenario are described in the following. First, a hand-held satellite device requirement is derived:

- The system shall be designed on the functional requirements regardless of the equipment specifications in order to be able to port some distress and safety functional requirements on a hand-held device for usage onboard small craft.

Second, satellite communications should following this requirement:

- The IMO carriage requirement for satellite terminals on ships specifies the carriage of equipment working in L-band. Larger ships typically also carry newer technology VSATs which

- operate in other frequency bands but which are not always globally available. The evolution of GMDSS will require a frequency band agnostic solution satisfying IMO existing functional and performance requirement.

Third, a GMDSS satellite provider diversity requirement is given:

- Capability of working with different satellite service providers (either global or regional).

Fourth, new Systems using Emergency Position Indicating Beacon (EPIRB) technologies requirements are needed. EPIRBs) are well established and have proved to be a great benefit to search and rescue. A system has been operated on 406.1 MHz by the Cospas-Sarsat partners since 1985 using initially LEO satellites which could derive position from Doppler measurements. The latency of the system is around one hour and GEO satellites have since been added which reduce the latency to around 10 minutes providing the EPIRBs are fitted with GNSS receivers and transmit a position derived from the GNSS. Inmarsat has also offered an L-band GEO satellite EPIRB service, again relying on GNSS, but this has since been withdrawn. Cospas-Sarsat are now intending to migrate their service to MEO satellites which will be able to determine position without needing a GNSS receiver and with reduced latency times. A further possible development is the introduction of a return link to the EPIRB (which currently does not contain a communication receiver) so that survivors can be notified that the EPIRB signal has been received. The Galileo satellites carry a suitable transponder for this. Marine EPIRBs also include a 121.5 MHz homing beacon which can assist in locating them by rescuing craft at sea. Very few ships however carry 121.5 MHz equipment which is an aircraft frequency. A possible development is to add an AIS beacon into the EPIRB as many ships carry AIS equipment which they could then use to find the EPIRB location. This again however relies on GNSS. This leads to the requirement:

- GMDSS should be able to operate with the new EPIRB service.

Finally, alternatives to HF communications are needed. High frequency (HF i.e. 3 to 30 MHz) communications were the traditional means of long distance communication for ships and are still used as a means of back-up to geostationary satellite services. There is now little commercial use made of HF circuits and the number of HF coast stations around the world is declining. It is possible that in future the GMDSS will not be able to rely on the use of HF due to lack of shore infrastructure. Therefore, a new user requirements arising from this is:

- An alternative to HF communications which supports voice and is capable of working from the ship’s reserve battery supply. (For e.g.: Inmarsat introducing next generation maritime safety voice and data service over the BGAN Fleetbroadband system)

7. Conclusion

This paper documents the areas of intervention to satisfy the future demands in 2020 for maritime communications, using the satellite technology. Identified areas are: e-Navigation, Arctic communications, autonomous ship and GMDSS. This paper provides for the four areas A description of the areas where the integration of satellite is able to increase the services availability in maritime market and a list of the user’s requirements

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