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Responsible Organisation: 1. SINTEF (MARINTEK) Contributing Organisation(s): 2. Telespazio S.p.A	Principal Author(s): 1. Ørnulf Jan Rødseth Contributing Author(s): 2. Nora Graziosi 3. Riccardo Nicolè
WP/HA leader Name: WP/HA leader Organisation:	Nora Graziosi Telespazio S.p.A

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1 List of Abbreviations

3G	Third Generation Mobile Technology (UMTS is a central component)
AIS	Automatic Identification System
AMVER	Atlantic Merchant Vessel Emergency Reporting [AMVER]. Similar systems are operating in Australia (AUSREP), Japan (JAPREP), Singapore (SINGREP) and other places.
BGAN	Broadband Global Area Network (from Inmarsat)
CALM	Continuous Air interface for Long and Medium distance (see 4.5.1)
CCTV	Closed Circuit TV (Typically for video surveillance)
COSPAS	Cosmicheskaya Sistyema Poiska Avariynich Sudov (Space System for the Search of Vessels in Distress) – see SARSAT
DECT	Digital Enhanced Cordless Telecommunications, e.g., cordless telephone
DSC	Digital Selective Calling, system for automatic transfer of call sign and other information via radio (see 4.1.1).
DSRC	Dedicated Short range Communication (see IEEE 802.11p)
EGNOS	European Geostationary Navigation Overlay Service
EPIRB	Emergency Position Indication Radio Beacon
EQUASIS	Voluntary and public database containing information on the ships identification and history, ownership, management, classification, safety, P&I (insurance) cover, Port State Control (PSC), deficiencies found and banning orders, private inspections, special certification, membership of associations and other [EQUASIS]
ETSI	European Telecommunication Standards Institute (member of ITU)
FDMA	Frequency Division Multiple Access (wireless access arbitration)
Fieldbus	Collective term for networks with limited node cost and, hence, limited range and/or bandwidth. Intended for interconnection of low cost, hard real time or other types of equipment that has particular requirements
GAN	Global Area Network (Inmarsat)
GEO	Geostationary Earth Orbit (Satellite)
GMDSS	Global Maritime Distress and Safety System: Typical use DSC service to implement distress calls
Grt	Gross Tonnage or Gross Register Tonnage is the internal volume of a vessel plus the space on exposed cargo decks (with some exemptions, depending on the assessing body). One GRT is about 2.8 m^3

HF	High Frequency, Maritime short wave radio
HIPERLAN	HIgh PErformance Radio LAN. It is defined by the European Telecommunications Standards Institute (ETSI). and is the European alternative for the IEEE 802.11 standards (WiFi)
HSC	High Speed Craft (see 3.1.4)
HVAC	Heat, Ventilation and Air Conditioning (System)
IAMS	Integrated Alarm and Monitoring System
IGO	Inter-Governmental Organisation
IMSO	International Mobile Satellite Organization (see INMARSAT)
IP	Internet Protocols
ISC	Integrated Ship Control
ITU	International Telecommunication Union
Kbps	Kilobit per second
LAN	Local Area Network
LEO	Low Earth Orbit (Satellite)
LOS	Line of Sight
LRIT	Long Range Identification and Tracking
MAN	Metropolitan Area Network
Mbps	Megabit per second
MEO	Mobile Earth Station (INMARSAT transceiver)
MF	Medium Frequency, around 500 kHz
MIN	Mobile Islands Network
MMSI	Maritime Mobile Service Identity (see DSC).
MPDS	Mobile Packed Data Service (for Inmarsat)
MRCC	Maritime Rescue Coordination Centre (sometimes called SAR centre)
MSC	Maritime Safety Committee (of IMO)
MSI	Maritime Safety Information (by NAVTEX or SafetyNET)
NAVTEX	NAVigational TEXt messages, also called narrow-band direct-printing: NBDP (see 4.1.6)
NBDP	Narrow Band Direct Printing; see NAVTEX

NMT	Nordic Mobile Telephony
PA	Public Announcement (System)
PWT	Personal Wireless Telephone (US variant of DECT)
QoS	Quality of Service
RORO	Roll On, Roll Off (Ship)
ROPAX	Combined passenger and RORO: Typically a combined passenger and car ferry
SAR	Search and Rescue (see also MRCC).
SARSAT	Search and Rescue Satellite-Aided Tracking
SCADA	Supervisory Control and Data Acquisition
SIRENAC	Ship Inspection Report Exchange, database run under the Paris memorandum of Understanding (MoU) to aid port state control [SIRENAC]. SIRENAC is used to establish white, grey and black lists for ships visiting Paris MoU ports
SOLAS	Safety of Life at Sea, IMO convention giving minimum requirements to ships in international trade [SOLAS]
SSAS	Ship Security Alert System (see 4.1.7)
SSB	Single Side Band (radio)
TESTA	Trans-European Service for Telematics between Administrations
TDMA	Time Division Multiple Access (wireless access arbitration)
TETRA	Digital trunked radio communication system (see 4.4.4)
UHF	Ultra High Frequency (typically for hand held radios), around 460 MHz
UAIS	Universal AIS (see this). Older abbreviation for AIS
UMTS	Universal Mobile Telecommunications System (component of 3G)
USCG	United States Coast Guard
VHF	Very High Frequency radio. The distress channel 16 is on 156 MHz. This is also the frequency band normally used for walkie-talkies onboard
VMS	Vessel Monitoring System, used in EU for tracking fishing vessels and enforcing restrictions on fisheries (see 3.1.6)
VSAT	Very Small Aperture Terminals (Satellite receivers)
WAVE	Wireless Access in Vehicular Environments (see IEEE 802.11p)

WiFi	IEEE 802.11 type wireless network protocols and equipment. Note that WiFi actually means that equipment has been certified according to certain technical standards, which may exceed IEEE 802.11 in some cases
WiMax	IEEE 802.16 type wireless network protocols and equipment. Note that WiMax actually means that equipment has been certified according to certain technical standards, which may exceed IEEE 802.16 in some cases
WLAN	Wireless Local Area Network: It is network that uses radio links to connect two or more computer without cabling or wires. Typically spread-spectrum technologies are used to connect devices within a relatively limited area. The uninterrupted mobility of users is also supported

2 Executive Summary

This document gives an overview of state of the art on maritime communication technology and requirements. Although the main focus should be broadband, the report is relatively broad in scope to also cover mandatory communication requirements and technology.

This document aims at establishing a common understanding of concepts encompassing maritime operations, along with a comprehensive presentation of current maritime services and supporting telecommunication technologies. The results of the SoA analysis will drive the definition of the methodologies applicable to the reliability analysis of critical components, discussed in D2.2.C.2, and to the collection of information on user-related service requirements, worked-out in D2.2.C.3. From the services and telecommunication technologies available in the state of the art, and from the outcomes of D2.2.C.3, the MarNIS service and application requirements are defined in D2.2.C.4, and a broadband service platform architecture is designed with functional and operational requirements and specifications in D2.2.C.5. Finally the D2.2.C.6 reports on the Cost-to-Benefit analysis, aimed at assessing the proficiency of proposed solutions in supporting maritime operations, spanning from safety to security at sea, from commercial applications to crew welfare and ship/shore communications.

The organisation of the rest of the document is as follows:

Chapter 3 defines some general concepts and give an overview of the main groups of communication systems. It also defined the concept of Mobile Islands Network (MIN) that encompasses the idea that the ship shall be a mobile network integrated with the larger system of terrestrial and satellite based communication channels.

Chapter 4 outlines details on wireless communication technology. This includes required systems as well as commercial systems. The overview covers radio based digital communication, cellular networks, WLAN and satellite systems.

Chapter 5 gives a brief overview of some integrated service providers. These companies will typically provide turnkey solutions to ship owners, where one or more forms of ship to shore communication is included.

Chapter 6 describes a selection of wired systems used onboard ships. This is mainly to give an overview of the problems related to implement a general network on the ship. This includes safety related networks such as navigation, safety and navigation, business related network and more entertainment related networks.

Chapter 7 gives an overview of how communication technology is used by the ship, with emphasis on the onboard use that requires ship to shore links. This includes mandatory services, operational related services as well as entertainment and general communication.

Chapter 8 gives a short overview of some “databases” or networks that are used by the ship and other actors to retrieve or store information.

Chapter 9 gives a description of other projects that have provided background for the report.

Chapter 10 summarises some of the data provided in the report and relates it to the original idea of a mobile islands network.

A list of references can be found in Chapter 11.

3 Overview of concepts

This section describes terms and concept used in the report. This is mainly related to ship types, operational areas and internal network infrastructure on ships and on shore.

3.1 Ship types

IMO [SOLAS] regulations basically apply to ship on international voyage that carry more than 12 paying passengers (passenger ships) or are larger than 500 Grt (cargo ships). This is defined in SOLAS I, A.2 and A.3. Some exceptions exist for naval ships, fishing ships and some other specialised vessels. For specific radio communication requirements the cargo ship size limit is defined to be 300 Grt (SOLAS IV, A.1).

SOLAS operates with subdivisions of ships similar to what is used in the table in the next section, but requirements for radio communication equipment is mostly independent of ship type. The distinctions between some of the ship types, including some not covered by SOLAS or recognised by SOLAS, are listed in the below sections.

Requirements for carriage of radio equipment are mainly controlled by the sea area the ship operates in (see sections below). Some variations exist for special ship types. As a result of this legislation, more and more ships are now carrying Inmarsat satellite communication equipment. However, basic regulations do not mandate particularly high bandwidth equipment.

3.1.1 Passenger ships

These ships are characterised by having more than 12 *paying* passengers. This has given rise to discussions of the concept “super yacht” (see below). Many passenger ships fall in the category of cruise ships or cruise ferries. These ships will typically have much more advanced communication equipment, partly to increase safety and efficiency but mainly as a service to passengers.

One should note that certain “seasonal” passenger ships, e.g., for pilgrim transport might be exempt from certain parts of the SOLAS regulations by the flag state.

3.1.2 Super Yacht

Many private yachts can carry more than 12 (non-paying) passengers. These are not covered by SOLAS or only as cargo ships, i.e., by being larger than 300 or 500 Grt. There is no reason to believe that SOLAS will be covering these ships in the future, but national governments, e.g. Italy, UK and the Netherlands have special national legislation covering these.

Again, due to high price and demands from passengers, these ships will typically be equipped with advanced communication systems.

3.1.3 Large passenger ships

This term is not defined by SOLAS but has been used in internal IMO committee discussions without anyone being able to reach an agreement on what exactly this is. The obvious problem is that the need for legislation for ships carrying 13 passengers need not be identical to ships carrying 4000.

As a rule, the owners of larger passenger ships will normally invest quite a bit more in passenger safety than what is required by SOLAS. This due to the loss of passenger confidence a casualty or an emergency onboard such ships could cause.

3.1.4 High speed craft (HSC)

High-speed crafts (HSC) are defined by having a maximum speed greater than a certain value that is dependent on their displacement. Typical operating speeds for such ships in UK waters are between 28 and 45 knots [ANM23].

For certain HSC regulations, the ship shall be operating in a trade that brings it less than 4 hours (passenger) or 8 hours (cargo) normal sailing distance from a place of refuge. Thus, HSC will often operate relatively close to land and may make use of land-based radio for communication.

3.1.5 Offshore supply vessels

In addition to general SOLAS requirements, these are covered in a special convention [OSV]. With regards to communication, this convention will require some additional reports regarding coordination between base, ship and offshore installation.

Many OSV and particularly those operating in the North Sea will usually have fairly good communication systems. This is normally required to rapidly adapt to new instructions.

3.1.6 Fishing vessels

Fishing vessels are covered by a separate convention [SFV]. This convention puts more limited requirements on the carriage of radio equipment. However, the European Commission has required all fishing vessels unless only doing “small scale” fishing to carry a “blue box” for Vessel Monitoring Systems (VMS) [EU2846].

In the Pacific, VMS have been successfully introduced for domestic fishery management in Australia, New Zealand and Hawaii. Other countries, which have recently set up national VMS, include Argentina and Morocco [FFA].

3.1.7 Cargo ships

Cargo ship is a collective term for other ships than those mentioned above. It will again be specialised into, e.g., tankers, bulk etc. These distinctions, which are also part of SOLAS, are mainly used to regulate various aspects relating to strength, stability or danger of pollution.

Cargo ships range from relatively complex (e.g., reefers, chemical tankers) to relatively simple (e.g., bulk or container). Both cost of ship and value of cargo as well as trade will influence what communication systems are installed. Minimum requirements are relatively low.

3.2 Approximate fleet count for ship types

ICL [ICL03] publishes shipping statistics and with that a count of the ships in different categories. The Table 3-1 is a summary of the counts published in the 2003 edition of this book (figures for 2002 mostly, the counts typically change a few percent each year). A similar search was done on the Lloyds Fairplay database [LRF], which is also the source for the ICL figures. The LRF database figures should be current as of date of writing (start of 2005).

Note that these statistics vary. Different group definitions and different weight limits influence the result. However, the table gives a certain impression of how the world fleet is composed.

Table 3-1 Ship types and counts

Type	ICL	Tot. ICL	LRF	Tot. LRF	Comment
Oil tanker	7 397	15 860	11 526	18 236	Total tank and bulk
Chemical tanker	1 290				
Liquid gas tanker	1 120				
Bulk	5 870		6 710		
OBO	183				
Container	2 905	19 573	3 255	22 678	Total cargo
General cargo	13 061		15 949		
Refrigerated cargo	1 225		1 243		
Special cargo	1 200		241		
RORO Cargo	1 182		1 990		
Cargo Passenger	220	3 882	2 756	6 098	Total passenger ships
RORO Passenger	2 261				
Passenger	1 401		3 342		
Yachts < 300 Grt			375	792	Total Yachts
Yachts > 300 Grt			472		

The total international fleet size at the start of 2005 was, according to [LRF], 47 012 ships, excluding yachts.

Comparable numbers for the fishing fleet is 24 181 ships. For the offshore fleet, the number was 2 962 and for other special ship 339 (typically research vessels). All the latter counts were for ships greater than 100 grt and according to [LRF].

3.3 Classification of sea area

SOLAS IV, A.2 defines sea areas A1 to A3 pertaining to radio communication requirements. A4 is the area that is outside A1 to A3. These areas are listed in the Table 3-2, together with indicative area names sometimes used in this document.

Note that for sea area A3, one should distinguish between ships operating in a relatively restricted area, which is covered by one of the other commercial satellite providers than INMARSAT and ships that are not. The former will, if they need higher bandwidth, have a greater selection of service providers and also prices for the services. This is typically the case for cruise ships or ferries that operate in a relatively restricted area, e.g., the Caribbean area or in the North Sea.

Table 3-2 Sea areas

Sea area	SOLAS	Description
Port		In port, at berth or approaching port. Area may be accessible by land based WiMax or WiFi systems. By SOLAS definitions, this will normally be an A1 area.
Shore	A1	An area within the radiotelephone coverage of at least one VHF coast station in which continuous DSC alerting is available
Coastal	A2	An area within the radiotelephone coverage of at least one MF coast station in which continuous DCS alerting is available (outside A1).
High seas	A3	An area within the coverage of an INMARSAT geostationary satellite (outside A1 and A2).
Arctic	A4	Area outside INMARSAT coverage, i.e., mainly Arctic and some parts of Antarctic.

Area A1 is about 30 to 50 km from the coastal radio station whereas area A2 goes out to about 230 km. The A3 area extends between 70º North and 70º South. Note that 70º south and southwards is mostly land or ice.

3.4 Classes of communication requirements

The emphasis in MarNIS is to provide general two-way communication facilities between the ship and shore with *sufficient* bandwidth. Sufficient is a relative term and heavily dependent on the ship type. In the scope of MarNIS one can as a starting point define the following classes of communication requirements:

a. *Minimum requirements:* This is defined by SOLAS and can as a minimum involve radio communication equipment with no digital capacity beyond what is implemented in GMDSS (DSC, NAVTEX etc.). This class requires voice communication for all but some distress notifications.

b. *Efficient reporting*: This would imply that a ship can send and receive mandatory and operation related reports without problems. A rough estimate is a transmission requirement of below 64 Kbytes per 24 hours. Receive requirements are probably lower. This could easily be handled with line speeds of below 9600 bits/sec.

c. *Efficient operation:* Given that operational processes are more moved to shore, efficient operation would require more (automatic) reporting from the ship, e.g., on machinery condition, remaining consumables, various special requirements for port calls and so on. Line speeds of 9600 bits/sec will probably provide the required transmission rates although volumes may easily be doubled or more compared to the previous class.

d. *Online ship:* This concept covers a ship that can be put online for remote maintenance, system diagnostics or for other purposes. This could include updates of digital weather forecasts, navigational maps etc. This requires a relatively high total capacity and also higher available bandwidth. A somewhat uninformed guess is on the order of a megabyte per 24 hours and minimum 64 Kbit/sec. This would also be sufficient for on-line emergency coordination, i.e., exchange of emergency related status and planning information between ship and shore.

e. *Broadband ship*: Passenger ships; research ships and other ships that require transmissions of large quantities of data also require high capacity communication links. This may mean rates of 1 megabit/sec or more and correspondingly high volumes of data.

One should note that for a relatively standard cargo ship, substantial gains in operational efficiency and safety could be had with b or c communication classes. Also one should note that data requirements change as the ship enters or leaves various sea areas. Typically, data transmission requirements will normally increase substantially as the ship nears port. This opens up for more cost-effective communication by using a combination of communication mechanisms.

Chapter 5 will look into these issues in more detail and references for actual ship communication requirements can be found there.

3.5 Types of communication systems

Regarding ship-shore communication one can roughly group them as done in the following sections. The groups and descriptions are mainly taken from [TUB91] and [SWAN] and enhanced with other sources where noted.

The discussion is mainly on the capacity for digital transmissions although many systems also carry voice.

3.5.1 Radio: VHF, HF or MF

While all ships are equipped with radios, these systems are not usually very suitable for digital communication. Some VHF and HF radio based digital communication systems exist, like the IMO mandated broadcast NAVTEX system (see 4.1.6) and the commercial CruiseEmail (see 4.2.1).

The main problem with VHF and lower frequency radio based systems is a relatively low upper throughput on total number of messages in the system due to shared bandwidth, limited number of channels and low bandwidth in each channel.

3.5.2 Cell-phone systems

The cell-phone systems will be usable near shore or in port areas. Different systems exist, of which GSM probably is the best known. Third generation cell phone systems promise standard data rates of up to 384 kbit/s for mobile users and can be a good alternative for ship-shore communication in costal areas. However, range is limited. The paragraphs 4.2.5, 4.2.6, 4.2.7, 4.2.9 give a more detailed overview of these systems.

3.5.3 WLAN – Wireless Local Area Networks

WLAN as a metropolitan network is already being deployed. This means that WLAN services are being made available to paying subscribers in a geographic area beyond a single building and by independent operators. However, range with current technology is very limited and is currently of practical use only inside ports or onboard ships. New technologies may change this, but will still have shorter range than cell phone systems. Section 4.3 looks into this technology in more detail.

3.5.4 INMARSAT

Satellite systems operated by the International Maritime Satellite Organisation (IMSO), are important elements of the maritime safety services (GMDSS). They support a number of different satellite services, each with its own dedicated ship borne transceiver over a constellation of geo-stationary satellites. The Inmarsat satellites are covering the entire ocean surface from latitudes of 76º N to 76º S (Sea Area 3, see Figure 4-4). Although INMARSAT is a very convenient system for fulfilling SOLAS requirements to GMDSS, it is not mandatory. Ships may operate in Sea Areas 3 by using MF radio instead of INMARSAT. However, most new ships can be expected to have INMARSAT onboard as the combined use in GMDSS and for general high seas communication is a good combination.

Unfortunately, INMARSAT has traditionally been rather expensive to use and this has been a serious limitation for "broadband" communication at the high seas. Section 4.7 looks into the technical issues of INMARSAT.

3.5.5 Other commercial communication satellites

Several other communication satellite systems offer services also at high seas through VSAT (Very Small Aperture Terminal) equipment. However, most operate with narrow beams and GEO (Geostationary Earth Orbit) satellites and only provide their services in limited areas. Section 4.9 looks into VSAT technology.

One notable exception is the LEO (Low Earth Orbit) system Iridium that provides worldwide communication services, but currently at relatively low bandwidth. Section 4.5 looks at LEO systems.

3.5.6 Broadcast satellites

Most communication satellites can also be used in broadcast or multicast mode. This will normally be a cheaper way to reach a high number of subscribers and is often used by both INMARSAT and VSAT equipped ships.

In addition, it is also possible to use dedicated broadcast satellites, e.g., as normally used for television, to broadcast messages to a large number of ships. This is particularly useful for data that is not intended for a specific ship, such as weather data, updates to electronic maps or notices to mariners.

Broadcast use will normally be most applicable to GEO type satellites as these have a defined geographic region they transmit to.

3.6 Network infrastructure onboard

Although this document is mainly concerned by communication between ship and shore, it may also be useful to look at the communication networks used onboard the ship. Figure 3-1 gives a schematic overview of the most common network types.

The networks have been grouped vertically in three main groups:

- *Safety related*: Networks that are critical for the ships safe operation. This includes, e.g., nagiation systems, fire alarm systems, automation systems, some cargo systems etc. The networks are usually not interconnected to avoid potential problems with propagation of faults. The networks are also typically redundant or in other ways made more robust.
- *Commercial/Business*: These are business critical networks that carry traffic that is critical to the commercial operation of the ship. This may be the general office network or networks associated with supervision of non-dangerous cargo and passenger invoicing. These networks can easily be integrated, but restriction on network technology may limit open integration.
- *Infotainment*: Entertainment and non-critical information to the crew and passengers. This may be included in the commercial/business category, but usually invoicing is handled by separate mechanisms not necessarily being dependent on the network itself, i.e., invoicing applications in gateway or management systems.

The networks have also been classified according to technology (shaded areas). From the upper left corner and diagonally towards the lower right we have:

- *Standard Internet protocol:* These are networks that are based on standard internet technology and rarely anything else. This is typically Internet access points for crew or passengers or office networks.

- *Various digital networks:* This is a group of networks that may be be a combination of Internet technology (typically on high level) and other types of technology (e.g., Fieldbus technology on lower levels). The Internet networks may often use less common application protocols, e.g., OPC [OPCDA], MODBUS over TCP [MBTCP], IEC 61162-4 [IEC61162-4] or similar protocols based on underlying IP standards.
- *Other networks:* Traditionally, voice communication has been analogue or at least been in a digital format not directly open for other use. However, new developments show the use of IP type protocols also in these areas. Voice over IP (VoIP) is more and more being used both for telephone type applications and public announcement systems (PA), also on ships.

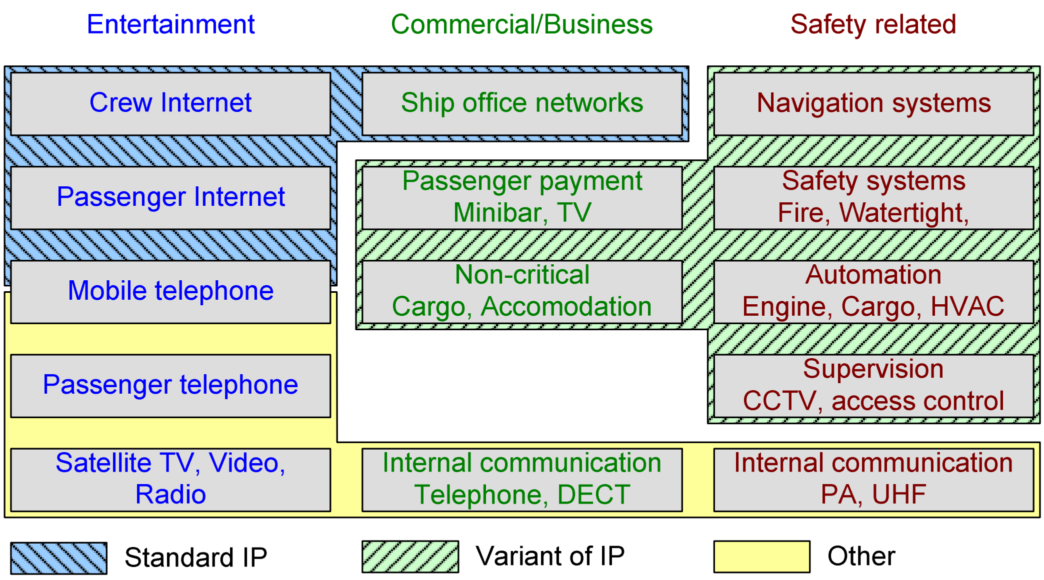

Figure 3-1 Common ship network types

As noted above, safety and security considerations have so far limited the degree of interconnection between networks. However, with the increasing use of IP technology and new extensions to this, e.g., virtual private networks, it is becoming feasible to look at increased integration.

3.7 Interface between on-ship and off-ship communication

With a reference in the previous figure, one can indicate how off-ship communication typically is interfaced to onboard systems. A schematic representation can be found in Figure 3-2

The figure shows the same components of the shipboard network architecture as in the previous figure, but indicates where off-ship communication links are most commonly interfaced to the onboard system:

- *Dedicated navigational services.* There are a number of navigational services that are used in conjunction with dedicated bridge equipment. This may include GMDSS, NAVTEX and other types of services. These servies will normally not be available for other systems at all.
- *Radio and sattelite voice communication:* These services are mandatory (if no digital equivalent is in place) and are associated with the communication equipment on the bridge. These services may or may not be made availbale to crew and other passenger through various forms of "gateways" (lower part of figure).

- *Digital satellite systems*: These systems are normally connected to the ship's office network and may be made available to crews and passengers through gateways (upper left). There may also be gateways to the monitoring, automation and control networks (upper right). This gateway will have to isolate any form of "attack" from more open networks to the safety critical control functions.
- *Infotainment systems*: Passenger ships may also have interfaces to more entertainment oriented communication systems, e.g., TV satellites. These would normally be connected directly to the onbaord information and entertainment networks.

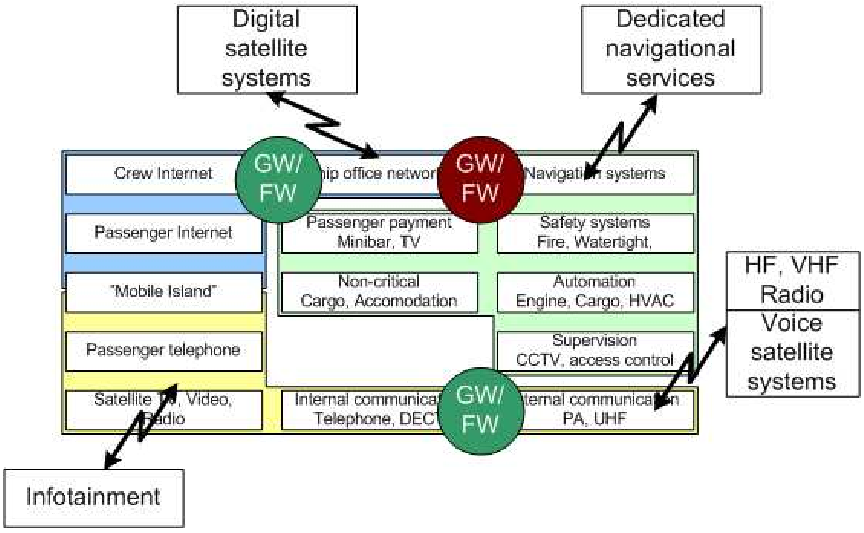

Figure 3-2 Interfaces between off- and on-ship networks

An interesting possibility in this context is ship wide wireless networks. One example of this is the Mobile Island Network (MIN) concept. This approach is based on the concept of an advanced architecture and communication infrastructure able to provide broadband connectivity for multimedia applications. Such an approach is particularly suitable to those situations where a high concentration of users can be found within rather small coverage areas. A local network, named Mobile Island Network, can be realised around a transportable node able to provide local connectivity to end-users (that could be, for instance, either of UMTS type to mobile terminals or IP type to LANs). This Mobile Islands Network is obviously connected to a remote terrestrial backbone through bi-directional broadband satellite links that can give passengers cell phone access on the ship.

3.8 The mobile islands networks (MIN)

Modern ships have increasing communication demands, both internally and towards shore or other ships. This can be illustrated as in Figure 3-3. Each ship sails as a "Mobile Island Network" where systems onboard is more or less integrated and operates in most cases as an autonomous "mobile island". Ships can be integrated with shore-based offices and authorities, with ports or SAR/VTS with a number of systems, some of which rely on digital communication as will be discussed in the next chapter. Today, the communication (except certain mandatory systems such as AIS and DSC) is mostly via satellite, either INMARSAT or VSAT type systems.

In the future one can foresee that close to shore communication, particularly when nearing a port can use terrestrial networks such as third generation mobile telephone or WLAN technology.

When considering this picture, one can also easily imagine that a wireless network covering a port and its approaches; can also be used by the ship as part of the overall infrastructure.

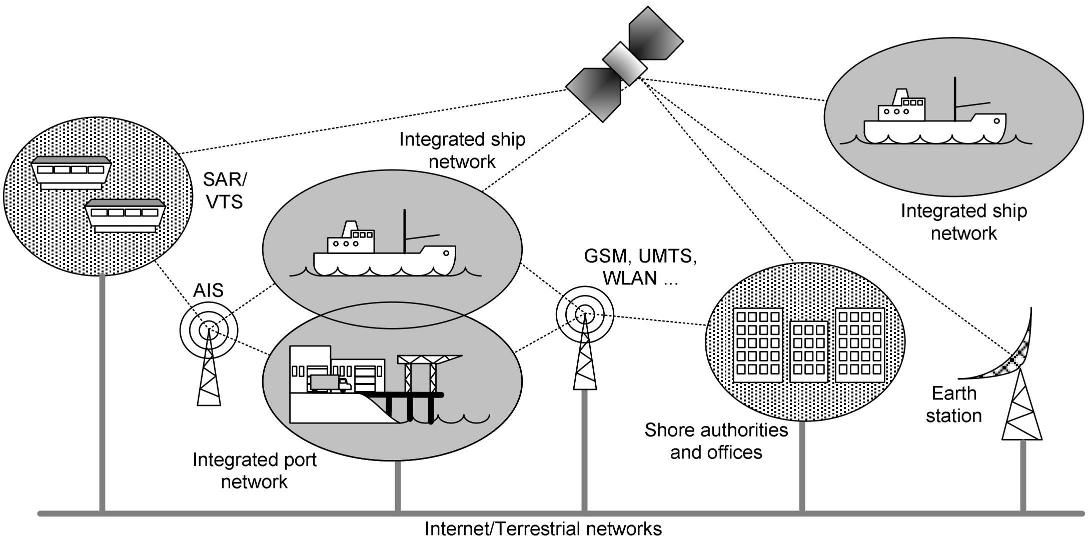

Figure 3-3 Mobile Islands Network

Thus, one can say that the mobile islands network concept consists of the following main components:

- *An integrated ship network* where a combination of wireless and wire based communication technology is used to create a homogeneous information access system for technical systems, crew and passengers;
- *An integrated port network* where arriving ships can beintegrated in an even higher level network system where maritime navigation and information services can be made available more efficiently than today;
- *An infrastructure* consisting of land based wireless communication services (e.g. WLAN and GSM), satellite based communication services and fixed wired services.

One should note that neither of these components requires significant technical development. The challenge is mainly to specify how existing and emerging technology shall be put together to achieve the overall goal of integrated information exchange.

Furthermore, it is also necessary to address both the port and the ship networks to determine how these can be integrated with terrestrial networks in the different ship “modes”, i.e., in port, along the cost or at high seas.

Finally, the terrestrial and satellite infrastructure has to be looked at as a boundary condition by MarNIS. The development of either is only to a miniscule degree driven by forces related to ship and shipping. The main commercial potential is in land-based industry. Thus, maritime users of the infrastructure will have to rely on systems mainly developed for other purposes.

Such an overall concept can also in principle be used for direct ship-to-ship communication, but this is probably not cost effective. Direct ship-to-ship communication is rarely necessary, except for navigational and emergency purposes. Navigation should in principle be handled by AIS and in some cases VHF and an emergency is a complex scenario that only to a limited degree relies on direct ship-to-ship communication. The issue will be investigated in later sections of deliverable D2.2.C.

One should also recognize the importance that Internet Protocols most likely will have for the concept of mobile islands network.

4 Wireless communication technology

This chapter gives a more detailed overview of the technology that can be used for digital communication between ship and shore. This is mostly wireless communication technology that can also be used onboard, e.g., as local GSM networks or in other contexts.

The following sections have used much material from the SWAN report on telecommunication systems [SWAN] and a similar report from TU Berlin [TUB]. Where other sources have been used, these are explicitly mentioned.

4.1 Special systems for support of legislation

4.1.1 GMDSS – Global Maritime Distress and Safety System

SOLAS Ch. 4, Part A, regulation 4 requires all ships at sea to have radio communication equipment that can perform the following functions:

- Transmitting ship-to-shore distress alerts by at least two separate and independent means, each using a different radio communication service;
- Receiving shore-to-ship distress alerts;
- Transmitting and receiving ship-to-ship distress alerts;
- Transmitting and receiving search and rescue coordinating communications;
- Transmitting and receiving on-scene communications;
- Transmitting and receiving signals for locating;
- Transmitting and receiving maritime safety information;
- Transmitting and receiving general radio communications to and from shore-based radio systems or networks;
- Transmitting and receiving bridge-to-bridge communications.

This is basically the content of the GMDSS regulation that was adopted by IMO to establish a better system for communicating information about accidents at sea. It implies carriage requirement for NAVTEX, DSC and/or Inmarsat emergency call systems and EPIRB.

In 1988, IMO amended the SOLAS Convention, requiring ships subject to it, to fit GMDSS equipment. Such ships were required to carry NAVTEX and satellite EPIRBs by 1 August 1993, and fit all other GMDSS equipment by 1 February 1999.

4.1.2 DSC – Digital Selective Calling

Digital Selective Calling is a central part of GMDSS. It uses a unique number for each radio set (MMSI – Maritime Mobile Service Identity) to be able to direct radio calls to and from identified ships or land stations. The MMSI can also identify a group of ships or land stations. The ITU has defined the structure of the MMSI so that it can be maintained on a national level, but used internationally. This is done by a component of the MMSI called MID - Maritime Identification Digits. Each country is assigned one or more MID, dependent on requirements.

The DSC system uses a special digital message to transmit information about the call being set up. This message is sent on a predefined channel that all radio sets listen to. The message contains:

- The caller's Maritime Mobile Service Identity or MMSI;

- The MMSI of the unit being called. This can be a specific unit or a group of units, e.g., all Coast Guard units;
- The caller's location, and time at location. Location and time at location are normally only transmitted with a distress alert;
- The requested working frequency and mode for the call being requested;
- The priority of call (Distress, Urgent, Safety, Routine);
- For distress calls, the DSC call can also indicate the type of emergency (fire, taking on water, etc). This is used in the context of GMDSS.

DSC can be used over MF, HF or VHF radio. INMARSAT uses a similar system as DSC as its native call mode.

Not much bandwidth is available and the system is basically not useful for other things than short alert messages.

DSC over VHF for emergency calls is being criticised for having an excessive high number of false alerts. Some administrations urge the migration to INMARSAT based services.

4.1.3 EPIRB – COSPAS/SARSAT

The carriage of EPIRB (Emergency Position-Indicating Radio-Beacon) is also mandated by the GMDSS code. It is a relatively small device that can be mounted on a ship or a lifeboat or can be purchased as a free-float unit. The latter will normally start transmitting data as soon as they are released.

Canada, France, the USA and Russia jointly helped develop a 406 MHz satellite emergency position indicating radio beacon (EPIRB), an element of the GMDSS designed to operate with COSPAS-SARSAT system. These automatic-activating EPIRBs, now required on SOLAS ships, commercial fishing vessels, and other ships, are designed to transmit to a rescue co-ordination centre vessel identification and an accurate location of the vessel from anywhere in the world [SARSAT].

An EPIRB from before 1997 does not encode the position of the sender in the signal and depends on a LEO satellite system (LEOSAR) to determine the position through Doppler shifts in the signal. Later EPIRB include position data in the transmission and can also use a GEO type system for faster response from a signal is sent to it is received by the MRCC. Also, positional accuracy is much better when position is included in message.

The bandwidth of transmission is very limited in this system and there is in principle no possibility to add payload to messages in the system.

Note that also INMARSAT-E implements an EPIRB service. This service is based on GPS provided position in all cases and is in general a more modern solution. There are also some other systems available.

4.1.4 AIS – Automatic Identification System

IMO have adopted regulations requiring all SOLAS crafts to be fitted with a universal automatic identification system transponder by 2008 at the latest. This device is now normally called an AIS transponder although the abbreviation UAIS has been used from time to time.

The AIS system uses a TDMA (time Division Multiple Access) scheme to allow up to several thousand ships to exchange important information on position, heading, speed, identity etc. This information can then be integrated with electronic charts and RADAR plotting systems to give a very good overview of the traffic situation.

Each message on the AIS "network" can have up to about 160 bits of payload. This is transmitted in a 256 bit long packet at 9600 bits per second. 23 different message types are defined and some of these allow the ship or shore station to send more or less arbitrary data, e.g., as "safety messages". However, the capacity is very limited, particularly when bandwidth has to be shared with several ships [IEC61993].

One should also note that a class B AIS is being standardised. This is an AIS for non-SOLAS vessels that are only allowed to transmit when no other transceivers send data. This is called a Carrier Sense TDMA technique (CSTDMA) [IEC62287]. Otherwise, it has the same technical characteristics.

The range of the AIS transmission is as for normal VHF, 25 to 40 nautical miles.

4.1.5 LRIT - Long Range identification and Tracking

When the AIS system was originally developed, the relatively short range was acknowledged and the need for a long range AIS system included in the specification. The functionality was not very well defined and only loosely related to the general AIS function. IMO has later found that it may not be necessary to have the same type of functionality as in the AIS system when operating long range [LRIT]. In particular, one should note that LRIT is not intended as a navigational aid as AIS is.

Subsequently, long range AIS has been renamed to long range identification and tracking to further distinguish it from AIS. Main use of LRIT will probably be:

- Extend VTS coverage beyond what is possible with basic AIS technology;
- Wide area or offshore monitoring of ship traffic including safety of navigation, search and rescue (SAR), resource exploration and exploitation and environmental protection in offshore areas including the continental shelf and economic exclusion zones (EEZ). In certain areas tank vessels must move in strict conformance with established Tanker Exclusion Zone (TEZ) regulations;
- Security related supervision, e.g., to ensure that ships destined for a known port do not rendezvous with other ships on its way.

The US Coats Guard has in particular been keen on the last issue. They are also propagating the original idea of continuous and fairly frequent reporting of ship data, as in AIS, also in the long-range version. Among other possibilities, they are investigating having standard AIS receivers onboard LEO satellites to record AIS data from ship in supervised areas [SaSN04].

To implement LRIT, one will have to rely on a satellite system. An obvious possibility is INMARSAT and possibly integrated with either SSAS or GMDSS. As noted elsewhere, INMARSAT-E already has a limited emergency transponder function (EPIRB) that could also be combined.

In [LRIT], a maximum message transmission rate of two to four messages per hour is quoted. This is sufficient for all but continuous tracking purposes (as USCG is now investigating). Message content is not quite clear, but it will most likely be of the same order as AIS messages, i.e., less than 100 bytes. Although this is a relatively small amount of data, one should keep in mind the size of the SOLAS fleet. If all ships are required to transmit their data several times per hour, the total amount of traffic will be significant.

4.1.6 NAVTEX

NAVTEX broadcasts are made on 518 kHz, using narrow-band direct printing transmission. The system uses special mechanisms for error corrections and relatively high integrity transmission. There are also additional frequencies for non-English (local language) transmissions. NAVTEX is used for urgent messages to ships in a restricted geographic area. The range of a land station is minimum 250 nautical miles (400 km). Bandwidth is very limited and all transmissions are broadcast. Communication is one-directional [NAVTEX]. NAVTEX is also called Narrow Band Direct Printing [NBDP].

4.1.7 SafetyNET

SafetyNET is an Enhanced Group Call (EGC) service implemented in the INMARSAT C system. It is a worldwide maritime safety information broadcast service of high seas weather warnings, navigational warnings, radio navigation warnings, ice reports and warnings generated by the International Ice Patrol, and other similar information not provided by NAVTEX. SafetyNET works similarly to NAVTEX in areas outside NAVTEX coverage. Ships sailing in waters not covered by NAVTEX must in most cases carry a SafetyNET system onboard [SafetyNET].

4.1.8 SSAS – Ship Security Alert System

A system for giving shore side warnings when a ship is attacked by terrorists, attempted hijacked or in similar cases has been mandated by SOLAS Ch. XI-2/6. This part of SOALS entered into force in July 2004 except for older general cargo ships, but will also cover these as of July 2006. The system is based on having a discreetly placed activation button on the bridge and will usually make use existing onboard communication equipment [SSAS].

Functionality is similar to GMDSS, but messages transmitted shall clearly indicate that the message is related to a security alert and not a safety problem. Note also that SSAS, unlike GMDSS, is mandated by functional requirements only. This means that Inmarsat as well as many other communication mechanisms, including the 406 MHz EPIRB, can be used to implement it.

4.1.9 Weather fax

Meteorological offices around the world send graphic weather information on HF fax broadcasts. Special weather fax machines can be installed on board to receive and print these broadcasts. This is not a mandatory system.

4.2 Commercial land radio based systems

This is not a complete overview of all individual services that are provided, but exemplifies some of the communication service types.

4.2.1 Low bandwidth over short wave or VHF

Commercial messaging services using standard maritime HF radio are now available as an alternative to Inmarsat. The company which paves the way in this direction is GlobeWireless that operates currently a network of 17 digital cost stations around the globe that are all controlled from a Network Operations Center located in Northern California [SWAN].

CruiseEmail [CEM] is another service that provides packet switched e-mail over SSB radio, both HF and VHF. It can reach large areas, and offer an effective bit rate of 150 to 400 bits/sec. It is low cost and has good coverage. However, as the medium has to be shared by all users and as the number of frequencies and stations are limited, there is a total throughput limit that makes it less useful for general ship use.

Also Telenor of Norway experiments with the same type of service over coastal radios and VHF. Here it is also claimed that this type of service may become a replacement for NAVTEX and VHF based GMDSS [TNMR]. This is reasonable as NAVTEX is a broadcast message that does not consume much bandwidth and GMDSS is only needed in exceptional circumstances.

Today, these services are primarily aimed at the leisure market with relatively low communication requirements. Except for the possible extension to NAVTEX and GMDSS services, it is not relevant for the MarNIS scope.

Similar services are also offered over public and free short wave radio, but with restrictions on commercial content in messages.

4.2.2 Telex

The maritime telex service is basically the same type of service as that described in the previous section, but within a more structured framework.

The Telia Mobile AB Maritex maritime extension to the Telex service operated for over 30 years but ceased operation on 31 December 2000. Telex messages for MARITEX subscribers can be forwarded via INMARSAT C. In its historical review of MARITEX, Telia report ‘Up to 1995, the traffic volumes in MARITEX were continuously increasing, despite the growing influence of satellite communications. Then came the implementation of GMDSS, with Radio Officers leaving the ships. It became obvious that systems like MARITEX needed some expertise to make full use of its capacity. HF equipment is in general more complicated to use than Inmarsat terminals. As a consequence, MARITEX faced a downward trend which has persisted ever since’ [SWAN].

Globe Wireless provides a worldwide maritime radio telex service. It includes a number of useful features that enable to overcome some of the limitations identified above. Information can be passed to / from email as well as to the normal shore telex network. To reduce the onboard operator impact and to provide operator convenience, a telex store and forward service is provided in both directions [SWAN].

It is considered that, in line with the reducing use in the land-based market, Telex will disappear from the maritime market in the next few years as more modern and trusted technology becomes accepted [SWAN].

4.2.3 Digital VHF

Telenor in Norway has recently started the deployment of digital VHF service in Norway. This is the continuation of a pilot project that has been running for some years. The specification for the transmissions is already being discussed in ITU and it is assumed that frequencies and transmission principle will be a new ITU specification in a reasonably short time. The system is using direct digital encoding of data on the radio signal and requires special receivers. The basic specifications for the system are shown in the Table 4-1.

Table 4-1 Digital communication over VHF

Bandwidth	21.6 kbps/character	Standard VHF channel, full duplex (single today)
Channels	15	Total capacity from one station: 324 kbps
Range	120 km	Dependent on topology
Power	5 W	Will be increased to 25W

The system supports seamless transfer between channels and base stations dependent on traffic and various load balancing algorithms.

The system is also constructed as a convention coast VHF radio, but enhanced to allow 100% transmitter duty cycle. It should din principle be suitable for safety related use, as e.g., NAVTEX and other critical messages transmissions. Thus, it could be useful as standard means for “broadband” transmissions to and from a VTS.

The system uses IP based packed mode transfer and interfaces directly to land and ship infrastructure through the Internet protocol.

As noted above, the system will be proposed as an international standard and it is already using channels allocated to digital transmission.

4.2.4 Digital communication on 450 MHz

With the introduction of GSM type cellular systems, the old 450-MHz mobile telephone system (NMT 450) has more or less lost its customers. In Sweden and Norway, these frequencies have been released to commercial interests that are planning to build a new type of digital mobile telephony system in this frequency range. The range of base stations are longer than for GSM type telephony and this may make the solution more interesting for ship use, although still in coastal areas. The system can also be used for wireless broadband services at a rate up to 2 mbps (http://www.nordiskmobiltelefon.se/front.asp).

4.2.5 Commercial cellular systems

The cell-phone systems will be usable near shore. [TUB91] gives a detailed overview of the various services offered and a short summary is shown in Table 4-2. The bandwidth is shown in kilobits per second.

Table 4-2 Overview of cell-phone digital transmission types

Bandwidth	Acronym	Comments
4.8	GSM multiplexed	Half rate normal GSM (not common)
9.6	GSM	Normal GSM
9.6 - 57.6	HSCSD	GSM Channel bundling, offered by some phones/networks. Allocates and locks bandwidth.
56 - 172	GPRS	Packet switched, bandwidth is not locked, usually 56 kbit, may get higher bandwidth.
56 - 474	EDGE	Enhanced data rates for GSM evolution, new coding scheme for GPRS. Allows 3 times data rate.
384	UMTS - FDD	Not widely deployed yet, but increasing.
2000	UMTS – TDD	Range problems, less used today

The drawback of this technology is limited range. A typical maximum reach of 10 km may be assumed. This means that the technology can be used near the shore or near offshore installations where base stations are deployed.

Note also that GSM networks can be installed onboard for the use of passengers or crew. As an example, Maritime Communication Partner AS [MCP] has already installed GSM networks on 12 passenger ferries. Also SatPoint AB [SATPOINT] provides the same service.

The following sections give a more detailed overview of the different technologies. The background is from [TUB] and [SWAN] where no other reference is made.

4.2.6 GSM, SMS and HSCSD

GSM or Global System of Mobile Communication is well known and proven to give good service in most areas of the world. Normal service offer data rates at up to 9.6 kbps. GSM has also specified a half-rate service by time-multiplexing two users onto the communication link. This service offers a data rate at 4.8 kbps. The full channel is allocated to the user (circuit switched) and the user pays per time unit, independent of actual use.

High Speed Circuit Switched Data (HSCSD) offers faster data transmission via a GSM network within the range 9.6Kbps to 57.6 Kbps. HSCSD increases the transfer rates of GSM network by channel bundling, allocating several channels to each costumer. Theoretical there are eight channels available, but currently up to four channels can be bundled. The total transfer rate attained by using simultaneously several channels is given as a sum of the rates of each channel (between 9.6 and 14.4 Kbps). Concluding a transfer rate of 38.4 and 57.6 can be expected from a connection with HSCSD. This is also a circuit switched system where payment is made for connection time.

SMS (Short Message Service) is an added feature of GSM that allows up to 160 characters to be transmitted in a single message. The SMS service is a store and forward service, much like electronic mail. This will most likely ensure that SMS will be complementary to other data transport modes through the GSM type network. One should note that the reliability of SMS varies between different service providers as different infrastructures are used.

4.2.7 GPRS and EDGE

The General Packet Radio Service (GPRS) is a new non-voice value added service that allows information to be sent and received across a mobile telephone network. It supplements today's Circuit Switched Data and Short Message Service.

However, the system uses the same radio frequencies and infrastructure and will subtract from existing capacity when used. However, GPRS supplements GSM by providing a different type of service in a more efficient implementation and one can expect a net total increase in capacity.

Theoretical bandwidth limit is 171.2 kbps. However, error correction and sharing of available time slots will significantly reduce this. 105 kbps or 56 kbps is expected as maximum real speed, perhaps lower in some cases. Other properties of the system may introduce variable propagation delays for packets and may make the service less suitable for “real time” type traffic.

Enhanced Data rates for GSM Evolution or EDGE is a new encoding system for the existing GSM network that increases capacity with a factor three. This means a higher number of users or higher bandwidth for each user. EDGE can be applied both to packet switched and circuit switched systems. As enhancement to GPRS, EGPRS is capable of offering data rates of 384 kbps and, theoretically, of up to 473.6 kbps.

4.2.8 UMTS and 3G

IMT–2000 or 3G (Third Generation) systems is a set of requirements defined by the International Telecommunications Union (ITU). IMT stands for International Mobile Telecommunications, and "2000" represents both the scheduled year for initial trial systems and the frequency range of 2000 MHz.

The main characteristics of IMT–2000 are a single family of compatible standards that have the following characteristics:

- Used worldwide;
- Used for all mobile applications;
- Support both packet-switched (PS) and circuit-switched (CS) data transmission;
- Offer high data rates up to 2 Mbps (depending on mobility/velocity);
- Offer high spectrum efficiency.

One of the most important IMT-2000 standard is the Universal Mobile Telecommunications System (UMTS). It is intended as successor for GSM. Different protocols exist to implement UMTS. Basically there is a trade off between mobility (speed of mobile station) and bandwidth. Thus, one can expect up to 384 kbps for very mobile users and possibly up to 2 Mbps for slower moving users.

UMTS will also use new and wider frequency bands and thus increase the total available bandwidth. It has a very high bandwidth efficiency and a typical total capacity per cell is 1 Gigabit per second [UMAL]. Typical maximum range for all GSM related services is about 10 km. One may expect somewhat longer range over open sea. Note that longer range also implies larger cells.

4.2.9 Digital Audio Broadcast

DAB or Digital Audio Broadcast is a uni-direction broadcast service being used for transmission of public radio. However, the system itself could also be used for broadcast of other information, such as electronic charts updates, weather information or navigational warnings. The below information is mostly from www.worlddab.org.

DAB can be transmitted on frequencies from the FM band (88 MHz to 108 MHz), but the services that have been introduced in Europe, Canada and Australia, together with pilots in India, are using other frequencies. Many countries (including the UK) are using Band III (around 221 MHz), formerly used for black and white television signals. Others like Germany and Canada are using L-Band (1452-1492 MHz). DAB receivers currently on the market can receive both Band III and L-Band transmissions. In 1992, the World Administrative Radio Conference, which is the internationally recognised meeting that assigns all the world's radio spectrum usage, allocated the L-Band frequency range to digital broadcasting, both terrestrial and satellite.

DAB uses a forward error correction scheme that gives a fairly high level of redundancy and good signal quality. The maximum capacity of one DAB transmission is approximately 1.7 mbps. This can be allocated to a number of individual channels with variable bandwidth dependent on application and required audio quality. Typically, one audio channel will use 192 kbps.

PC based DAB receivers are already available for a relatively low price and could be used to receive any type of digital broadcast signal.

4.3 WLAN systems

Wireless LAN systems are today mainly IEEE 802.11 or IEEE 802.16 compliant. The latter is still only recently published and yet without truly conformant equipment. The Table 4-3gives a very brief comparison between the different standards.

Table 4-3 WLAN comparison

Standard	Mbit/s	Km	Comments
802.11b	11	0.1	Most common WLAN
802.11g	54	0.2	Faster and becoming common
802.16a	20-30	6-10	No roaming
802.16e	3-5	6-10	Roaming (standard probably available in ’06 or ’07)

In practical terms, there are some doubts about these numbers, particularly for the 802.16 standards. Note also that all distances are line of sight (LOS), with non line-of sight; these figures will be decreased significantly.

4.3.1 IEEE 802.11

IEEE 802.11 is a series of standards that are the current state of art (2004) for wireless LAN communication. It has reached a certain level of popularity and has also been deployed in various ports as a service to ships with WLAN capabilities. There are currently three variants of IEEE 802.11 WLAN standards in more or less common use. These are summarised in the Table 4-4[BC11].

Table 4-4 IEEE 802.11 comparison

Name	Mbit/s	GHz	Comments
802.11a	6-54 (8 variants)	5	Mostly deployed in US. Has not gained wide acceptance and will probably not do so.
802.11b	1-11 (4 variants)	2.4	This is the most common WLAN type in use today (2004).
802.11g	1-54 (12 variants)	2.4	This is the up and coming WLAN-WiFi standard. Compatible with 11b.
802.11n	100 to 500?	2.4 or 5	Maybe available in late 2006, should handle multi path problems better and increase range and speed.
802.11p		5.9	Not yet available, but should support up to 6 mbps up to 300m. Roaming access is promised.

Certification of devise for compatibility with the specification is done by the independent industry association “Wi-Fi Alliance”. Although the term “WiFi” formally is reserved for certified devices, it is often used as a general term for IEEE 802.11 systems and devices.

IEEE 802.11a uses frequency bands that are mainly available in the US (5 GHz) and is not considered a general international standard. 11b and 11g uses non-licensed bands (2.4 GHz) that are globally available, although susceptible to disturbances from other systems operating in the same bands.

Today, metropolitan WLAN networks have been installed to service various official functions like emergency management and surveillance. An example is a WLAN network installed in the Port of Oakland in the USA [PRWP].

Today’s WLAN technology is mainly based on the WiFi standard (IEEE 802.11 series), with new WiMax devices starting to appear (IEEE 802.16 series). Figure 4-1 gives a very rough overview of the capabilities of the WiFi related standards. Note, however, that various technical solutions have been demonstrated to improve these ranges.

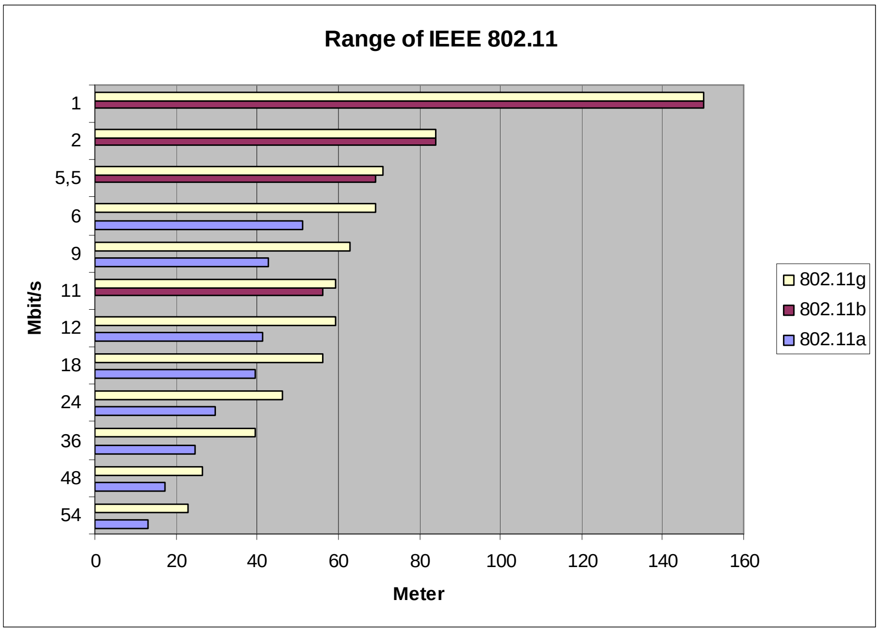

Figure 4-1 Theoretical range of IEEE 802.11

IEEE 802.11b and 11g both use the 2.4 GHz band and have similar propagation characteristics. The approximate ranges for the different bit rates are plotted in Figure 4-1 [BC11]. Note however, that longer ranges can be achieved by more sensitive and directional antennas. A capacity of up to 1 mbps over 24 km range was achieved for a test ship in USA [DS2002]. Also the port of Amsterdam reportedly covers up to 2000m from shore with WiFi systems [RN04].

The IEEE 802.11p Task Group was established for Wireless Access in Vehicular Environments (WAVE). The Dedicated Short Range Communications (DSRC – US project for roll toll collection etc.) is a general-purpose communications link between the vehicle and the roadside (or between vehicles) using the 802.11p protocol. Thus, the p-variant may be more appropriate for fast moving vehicles than for ships.

IEEE 802.11n is being worked at to increase speed and to decrease problems of multi path disturbances. Two proposals are at the moment on the table (mid 2005), one to use the 11a 5 GHz band and one to use the 11b/g 2.4 GHz band. Both proposals do agree to specify MIMO (Multiple Input Multiple Output) antennas to increase noise immunity.

The 2.4GHz spectrum is already heavily populated with wireless devices and has only 3 non-overlapping channels available (which is why the narrower 20 MHz bands are suggested). At 5GHz, there are 23 non-overlapping 40 MHz bands (in the US). At 5GHz, wider bands and MIMO antennas could provide data transfer speeds to upwards of 500mbps versus a theoretical speed of 100-200mbps at 2.4GHz.

Because of environment, overheads and other factors, the effective throughput over a WLAN link is not the same as bit rate. For the highest speeds one can expect up to about 50% reduction in end-to-end throughput over TCP/IP [BC11]. For the lower bit rates, smaller reductions will be observed.

The standard is mainly intended for line of sight (LOS) communication and is sensitive to multi-path distortion. For this reason, indoor range is typically limited to about 30 meter.

Finally, one should also keep in mind that the overall capacity of a WLAN network is limited as it is based on concurrent use of a single medium. This means that more clients mean less bandwidth available for each. The 11g and 11b standards allow three non-overlapping radio channels which helps to alleviate the problem. Also, the distance limitation and use of multiple access point can help to increase the number of clients. However, there is in any case a limit to the bandwidth that is available.

802.11f - already part of most 802.11-based hardware - enables roaming among access points on the same network segment. However, roaming often breaks down as users move across network segments, especially for voice traffic.

4.3.2 IEEE 802.16

IEEE 802.16 is often called Metropolitan Area Network (MAN), meaning that it is supposed to take a major segment of the distribution of digital data in rural areas. Thus, it can be seen as a competitor to 3G cell-phone systems. As of time of writing, the IEEE 802.16a standard has been approved and tests have started on available equipment. This standard is a first variant that do not support roaming users and which have other limitations in performance (see below). IEEE 802.16e is under development and may be finished in 2006. This is a more advanced standard that may be more realistic as a real alternative to 3G.

An IDC report [IDC, abIDC] also sees WiMax as having a significant impact on the marketplace, but not in the short term. The report states that until 2008, one will probably not see any sizeable volumes that would be an opportunity for chip vendors or equipment vendors. IDC breaks the WiMax market down into three main categories: fixed wireless broadband for emerging and rural markets, wireless LAN hotspot backhaul, and laptop or handheld mobility with 802.16e. Both hotspot backhaul and emerging and rural markets present relatively small niche opportunities that aren't likely to justify the cost of implementation. Thus, this report sees the mobile market as the driving for this technology. This also implies that real market penetration cannot be expected before 2008.There is also a number of other fixed wireless technologies that compete with WiMax. In particular, it looks as if 3G perhaps has a larger momentum at this time.

WiMAX will support line-of-sight (LOS) at a range up to 50 km and non line-of-sight (NLOS) typically up to 6-10 km for fixed customer premises equipment (CPE).

The data rates for the fixed standard will support up to 75 Mbps per subscriber, peak, in 20 MHz of spectrum, but typical data rates will be more like 20-30 Mbps. The mobile applications will likely support 30 Mbps per subscriber, peak, in 10 MHz of spectrum, with 3-5 Mbps, typical. The base station will support up to 280 Mbps to meet the needs of many simultaneous users [WiMax].

The IEEE 802.16e standard has modifications designed to support subscriber mobility, which basically means a 15 Mbps (max.), 3-5 Mbps (typical), 3-6 km (indoor) and 6-10 km (outdoor) range [WiMax].

One should note that the numbers quoted above are not confirmed and there is a certain worry in the market that this performance will be difficult to obtain.

4.4 Other wireless technology

This section gives a brief overview of some other wireless technology that may have more peripheral interest in the scope of MarNIS.

4.4.1 HiperLAN

HiperLAN/2 (for High Performance Radio Local Area Network Type 2) is a new high-performance 5GHz radio networking technology, specifically suited for operating in LAN environments. HiperLAN2 is being developed by the European Telecommunications Standardisation Institute (ETSI) Broadband Radio Access Networks (BRAN) project.

HiperLAN/2 is a flexible platform for a variety of business and home multimedia applications that can provide a set of bit rates up to 54 Mbit/s. In a typical business application scenario, a mobile terminal gets services over a fixed corporate/public network infrastructure. In addition to QoS, the network will provide mobile terminals with security and mobility management services when moving. In an example home application scenario, low-cost and flexible networking is supported to interconnect wireless digital consumer devices

Specifications for HiperLAN (see http://www.etsi.org/t%5Fnews/0005%5Fbran.htm) are finished from ETSI, but it is not clear to what degree the specifications are translated in real products. The HiperLAN/2 Global Forum seems to have disappeared from the web.

4.4.2 IEEE 802.15 - ZigBee

IEEE 802.15 (ZigBee) is a new standard that may get some application in specialised areas. It is intended as a low cost and fairly high bandwidth solution for various wireless applications. Current implementation can reach 250 kbps over 70 to 100 m [ZB].

4.4.3 DECT

Digital Enhanced Cordless Telephony DECT and its North American sibling Personal Wireless Telecommunications (PWT) system is a cordless system intended for short-range (typically 200 metres) communication, operating in the 1880 to 1900 MHz band. It is mainly intended for use in indoor environments and private networks, which may include multiple handsets and base stations. Roaming between base stations is possible. Use of a handset on different DECT private networks (e.g. business and residential) is also possible. DECT has a very flexible radio interface that, besides voice allows standard DECT equipment to handle data at 24 kbps. The air interface design permits, in theory, much higher data rates (n x 24kbps, 552 kbps data is theoretically possible) but equipment operating at this speed or with such features are not easily available, and rarely with interoperable standards for digital communication.

DECT base station and handsets are operated under Line Of Sight conditions and equipped with the maximum allowed gain antennas, radio ranges up to 5 km are feasible (between base stations and handsets). Application of a Wireless Relay Station (WRS) – in the same constellation – extends the radio range by another 5 km. This means that DECT could theoretically be used as a cordless point to multipoint extension of the terrestrial ISDN network in port areas [SWAN].

4.4.4 TETRA

TETRA is a European standard, developed by ETSI, for digital trunked radio systems. TETRA systems focusing on the needs of professional mobile radio users: currently with emphasis on public safety and security (police, fire and rescue, customs, ambulance, etc.).

TETRA is a fully digital system providing consistent voice quality and low bit error rate for data. TETRA Voice and data uses a TDMA methodology that permits the use of one 25kHz carrier by 4 users simultaneously for voice or data applications at a bit rate of up to 7.2 kbps or up to 28.8 kbps if all four channels are reserved for the same user connection [SWAN].

4.5 Integrating protocols for support of mobile networks

4.5.1 CALM

CALM (Continuous Air interface for Long and Medium distance) is a new standard worked on by ISO TC204/WG16 and partly funded by EU through the Cooperative Vehicle Infrastructure Systems (CVIS) project. (See http://www.iso-calm.de/).

CALM shall support user transparent continuous communication capabilities over a wide range of transport media. Currently, the focus is on GSM (GPRS or UMTS) and WLAN, but satellite and other wireless technology can easily be supported. For WLAN, the effort is concentrated on IEEE 802.11p that is a developing standard for roaming and longer-range access.

CALM relies on the use of additional information in IPV6 headers. This is one of the potential drawbacks of the solution, as it is not clear at what time IPV6 will be established within the consumer area. This may or may not be a problem, dependent on how the system evolves.

For maritime use, it is not clear that CALM will be a significant contribution to broadband communication. Ships are moving slowly and are large entities where general Internet access probably will be performed through single gateways between ship and external communication carriers (see section on mobile island networks). Thus, built in support for roaming between communication carriers is not a critical factor. However, if CALM is established as a de facto solution for Internet over multiple carriers, with roaming access, and with support for infotainment there is no obvious reason why CALM should not be used.

4.6 Portable terminal satellite systems

Several systems have been proposed over the years, but only five seem to be active. Of these, one has no satellites in operation yet.

4.6.1 Globalstar

Globalstar offers telephone and data services (maximum 9.6 kbps) from 48 LEO satellites. It claims that it is the largest provider of mobile satellite communication services. The system is dependent on direct link to earth stations and can at this time only offer connectivity on land or near to land. Today coverage is over most of Americas and northern parts of Europe and Asia as well as Australia [GS]. As Iridium, Globalstar was close to bankruptcy, but is still operational. The characteristics of Globalstar are summarised in the Table 4-5.

Globalstar, as most of the other systems mentioned here is not really broadband, but is mentioned as reference (see also comments under Thuraya).

Table 4-5 Overview of Globalstar properties

Satellites	48 satellites + 8 spares
Ground Segment	38 planned gateways: 16 operative gateways and 11 gateways are in various stages of development
Transfer Mode	Packet switched

Multiple Access	CDMA/FDMA/FDD
Modulation	QPSK
Frequency Band	L and C bands, 11.4 MHz (shared with other CDMA operators)
Bit Rate	Voice at 4.8Kbit/s (when no speech is detected, the data rate is reduced to 1.2Kbit/s); Data bit rates as high as 9.6Kbit/s
Coverage	Global coverage provided that gateway coverage is available. Each satellite provides 16 spot beams to form a continuous overlapping pattern of coverage cells. Minimum elevation angle: 15° (minimum elevation angle of the satellites for the 90% of the time, as seen from a latitude of 48°) with two satellites over the horizon almost any time Mobile terminals can communicate directly only with a gateway that is visible from the serving satellite (mobile to mobile communication will therefore always involve a double hop) 768 beams; 1 always visible satellite
User Terminal	Hand-held (but bigger and heavier than cellular terminals); dual mode handsets allow to operate on either the terrestrial cellular channels or the satellite channels
Applications	Mobile personal communication for users in remote lands and over the seas. Fixed telephone communication in remote lands not served by fixed networks

Figure 4-2 shows the coverage of the Globalstar system (from www.globalstar.com). Orange area is standard coverage; other colours indicate lower quality service.

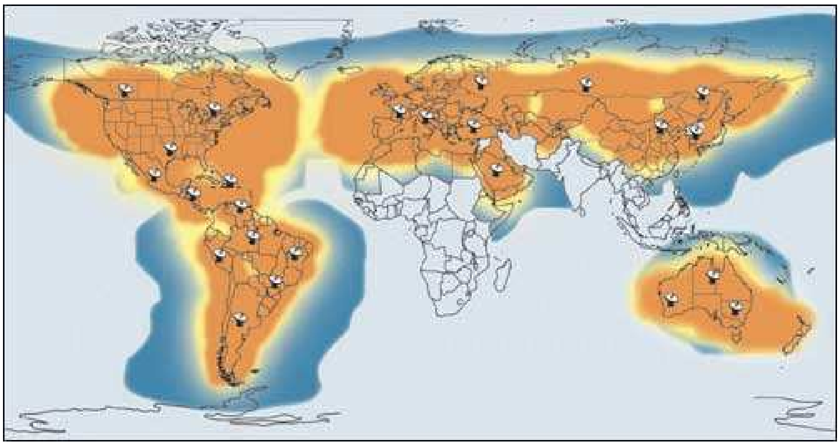

Figure 4-2 Globalstar coverage

4.6.2 IRIDIUM

After much financial trouble there has been some doubt about the viability of this system. However, it has been refinanced and is still operational. It is based on 66 communicating LEO satellites and offer cell-phone type services with handheld or fixed terminals. It is the only service that can give same service quality worldwide. Maximum data speed is 2400 bits/sec [IRIDIUM]. The Table 4-6 summarises the IRIDIUM characteristics.

Table 4-6 Overview of IRIDIUM properties

Satellites	66 satellites + 12 spares
Ground Segment	12 gateways, 4 control and telemetry stations
Transfer Mode	Packet switched
Multiple Access	FDMA/TDMA
Modulation	QPSK
Frequency Band	The subscriber links are in L-band between 1616 and 1626.5 MHz. Feeder links are in Ka band, with downlinks between 19.4 and 19.6 GHz and uplinks between 29.1 and 29.3 GHz.
Bit Rate	Voice and data at 2.4 kbps.
Coverage	Global coverage. Six satellites in 11 polar planes communicate with each other as well as with two satellites in adjacent planes. 12 ground stations transfer messages to terrestrial networks.
User Terminal	Hand held.
Applications	Mobile personal communication for users in remote lands and over the seas. Fixed telephone communication in remote lands not served by fixed networks

4.6.3 Orbcomm

Orbcomm has about 30 satellites operating in LEO polar orbits. They offer narrow band telemetry services at relatively low prices. Maximum speed is 2400 bits/sec uplink and 4800 uplink. The system can use store and forward in the satellite to give global coverage, although sometimes with a delay. It is mainly a system for transfer of measurement and event type data. The downlink from each satellite to earth station is only about 60 kbps, so overall capacity is not very high. However, the system provides full global coverage [OC]. The Orbcomm characteristics are summarised in the Table 4-7

Table 4-7 Overview of Orbcomm properties

Satellites	30 satellites
Ground Segment	12 currently, 5 planned
Transfer Mode	Packet switched
Multiple Access	FDMA
Modulation	Differential phase shift keying (SDPSK)
Frequency Band	VHF and UHF in range around 150 MHz and 400 MHz for a beacon service.
Bit Rate	2.4 kbps to satellite, 40 kbps from satellite, 57.6 kbps to ground station. Satellites are in view only for about 10 minutes. No hand over.

Coverage	Global coverage. Direct relay to ground or as store and forward.
User Terminal	Typically dedicated data acquisition units.
Applications	Short messaging, usually related to supervisory control and data acquisition (SCADA).

This system is also being considered by the USCG as platform for an AIS supervision system, where the coast guard shall be able to monitor positions of ships even outside the reach of land based AIS base stations [SaSN04].

4.6.4 Thuraya

The Thuraya mobile satellite system is a turnkey project built by Boeing Satellite Systems, formerly Hughes Space and Communications International, Inc. (HSCI).

Thuraya provides dual communication mode on standard GSM networks and its own satellite-based system. In satellite mode, the services are compatible with standard GSM, including short message service (SMS). It offers dual-mode hand held or fixed terminals with satellite and GSM connectivity, aiming to provide flexibility and continuous and cost-effective roaming for users. Essentially, Thuraya subscribers would continue using their national land-based mobile network, but will be able to automatically switch to Thuraya satellite mode in areas that are outside the range of the terrestrial system. Thuraya's hand held mobile terminals are comparable to GSM handsets in terms of size and appearance, as well as in voice quality.

Thuraya relies on two GEO satellites, on 44° E and 28.5° E and an inclination of 6.3°; Boeing is completing a third satellite. Thuraya's satellites have been specially designed to achieve network capacity of about 13,750 telephone channels.

Table 4-8 Overview of Thuraya properties

Satellites	2 satellites, 44° E and 28.5° E
Ground Segment	1 station in UAE
Transfer Mode	Packet switched
Multiple Access	TDMA (8 channels)/FDMA, total of 13,750 Satellite Traffic Channels
Modulation	pi/4 QPSK
Frequency Band	1526.5 - 1659 MHz
Bit Rate	Voice, data and fax (9.6 kbps), SMS and other GSM type services.
Coverage	See coverage map.
User Terminal	Combined GSM and Thuraya handsets or fixed antennas.
Applications	Personal mobile communication.

Figure 4-3 Thuraya coverage (from www.thuraya.com)

Thuraya is not a broadband system as such. Nevertheless it may represent a reference for the perceived QoS, for any foreseeable on-ship system to provide GSM-like connectivity, especially in the Mediterranean and Middle East area.

4.6.5 ICO

ICO Global Communications is planning to operate a number of MEO satellites to provide world wide mobile data and voice services. Data rates are planned to extend up to 144 kbps [ICO].

ICO Global Communications has had financial problems as most other operators in this segment and has recently restructured their business and is now named "New ICO".

4.6.6 Teledesic

This company got significant press coverage, as Bill Gates was one of the founders. The company is now out of business and have returned radio frequency licences to the government.

4.7 INMARSAT

4.7.1 General

INMARSAT came into being as an IGO (Inter-Governmental Organization) in 1979 to provide global safety and other communications for the maritime community. Starting with a customer base of 900 ships in the early 1980s, it then grew rapidly to offer similar services to other users on land and in the air, until in 1999 it became the first IGO to be transformed into a private company.

Inmarsat provides wireless two-way communication land services, aeronautical and, of course, maritime communications and safety services. INMARSAT is currently the only approved provider of GMDSS services via satellite. The International Mobile Satellite Organization (IMSO) has been created to supervise the company's public-service duties to support GMDSS as well as satellite-aided air traffic control for the aviation community. This makes Inmarsat a de facto standard for ships operating at the high sea, although ships in principle are allowed to operate GMDSS via short wave.

The INMARSAT system has four major components:

- A network of satellites provided by INMARSAT;
- Ground stations through which services are provided, often owned and operated by the signatories;
- Terminals carried by a wide range of mobile users;
- Centres at INMARSAT Headquarters: Network Operation Centre (NOC) and Satellite Control Centre (SCC) that monitor and control the system.

The space segment consists of three generation of geostationary satellites (I-2, I-3 and, now, I-4) that cover 4 worldwide areas:

- Atlantic Ocean Region - West (AOR-W);
- Atlantic Ocean Region - East (AOR-E);
- Indian Ocean Region (IOR);
- Pacific Ocean Region (POR).

Inmarsat I-3 satellites were launched at mid nineties to join and replace the previous generation I-2. I-2 provided global beam coverage; I-3 can generate a global beam and a maximum of seven spot beams. These are directed as required to make extra communications capacity available in areas where demand from users is high. The spot beams also carry the Mini-M service.

Table 4-9 Overview of Inmarsat properties

Transfer Mode	Packet switched
Multiple Access	FDMA/SCPC
Modulation	Depends on the particular INMARSAT standard: – BPSK (Inmarsat C, D+) – O-QPSK (Mini-M)
Frequency Band	– 1.6265-1,6605GHz (subscriber ↑ link) – 1.5250-1.5590GHz (subscriber ↓ link) – 6.4GHz (LES → satellite) – 3.6GHz (satellite → LES)
	Dynamic reallocation of both RF power and bandwidth among a global beam and five spot beams, allowing greater reuse of the available spectrum

Bit Rate	Voice: 2.4Kbps Data: up to 64Kbps 128 kbps ISDN
Latency Time	Real Time (store and forward for some messaging services)
Coverage	Global, within about +70° -70° latitudes. 97% of landmasses are covered. Each satellite's global beam covers ca. one-third of the Earth's surface. In addition, the system supports the "spot beam" technology in I-3 and I-4 satellites. Spot beam gives higher power and higher bandwidth for several of the services. The global beam is used for signalling and for general-purpose communication channels.

Figure 4-4shows global beam (ovals) and spot beam coverage for the Inmarsat system (from www.inmarsat.org).

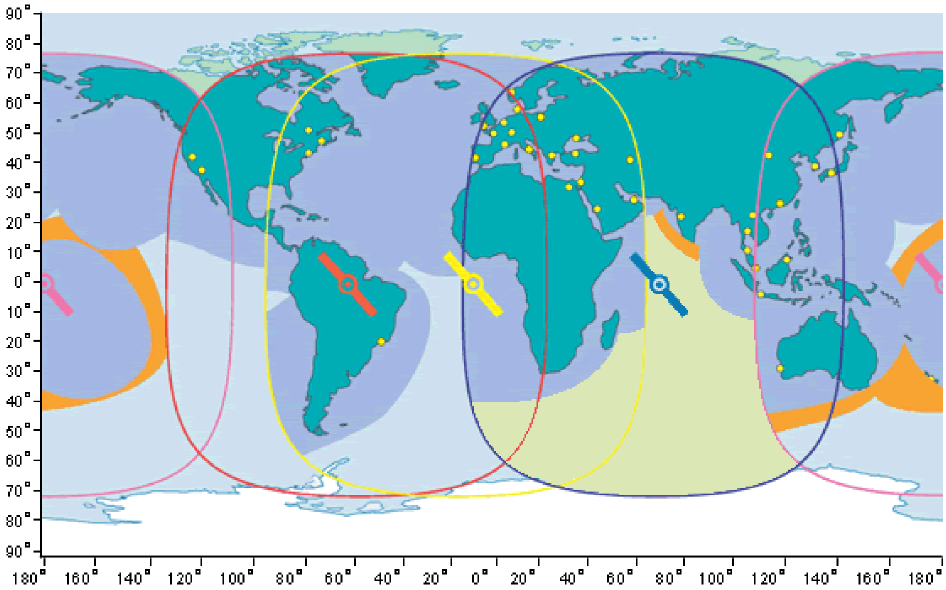

Figure 4-4 INMARSAT global and spot beam coverage

Inmarsat I-4's first satellite F1 was launched in March 2005 and it is becoming operational at mid 2005. It represents the first component of the forthcoming Inmarsat broadband services or, as the company has called it "Broadband Global Area Network" (BGAN). According to Inmarsat, this will allow extended coverage and broadband services up to 492 kbps. However, the high speeds will most likely be offered in the spot beams only.

The new I-4 satellites are able to form up to 19 wide and 228 narrow spot beams: The first satellite is covering the Indian Ocean Region (IOR).

Inmarsat offers various maritime services. The most important services for the maritime sector, up to the introduction of the fleet range of services were:

- Inmarsat Mini-M for voice and low data rate services;
- Inmarsat D+ for short messaging and positioning services;

- Inmarsat C/mini C and Inmarsat E+ for low narrow band data exchange and GMDSS compliant applications.

Recently, Inmarsat has put more emphasis on a new range of fleet services:

- Fleet33: Global telephone, and Mobile Packet Data Service (MPDS) at a maximum rate of 9.6kbps mainly aimed to the small vessel market;
- Fleet55: Same as previous, but bit rates up to 64 kbps using medium sized antennas for medium size vessels;
- Fleet77: Adds to previous services the Mobile ISDN for a bitrate up to 128 kbps. This service is compliant to IMO A.888 for GMDSS.

Fleet Services mainly provide high-quality mobile voice and flexible data communications services, e-mail and secure Internet access for the maritime industry. The actual bandwidth is expected to increase along with the further deployment of Inmarsat I-4.

The global ISDN and MPDS services are named "Global Area Network" (GAN) in the Inmarsat terminology. Only Fleet77 gives high capacity services in the global beam area.

4.7.2 Data Reporting Service

The Data Reporting Service is designed for the efficient transmission of small quantities of data (max. 32 bytes). Data reports are transmitted via signalling channels that are part of the Inmarsat-C network. By transmitting through these signalling channels it is unnecessary to return to a message channel meaning that the data reports can be exchanged much faster than normal messages. As data reporting uses the signalling channel, positive delivery notifications are not possible. This may be a problem in certain applications, as it has also been seen in practical use that some messages disappear in the system.

4.8 VSAT systems

VSAT (Very Small Aperture Terminal) refers to a combined send/receive terminal, with a typical antenna diameter of 1 to 3.7m. VSAT networks are well suited for business applications, offering solutions for large networks with low or medium traffic. They provide very efficient point-to-multipoint communications, are easy to install, and can be expanded at very low extra cost. VSAT satellites operate in GEO orbits.

They offer immediate accessibility and continuous high-quality transmissions. And as they are adapted for any kind of transmission, from data to voice, fax, high-speed Internet, and video, VSAT networks offer the operational flexibility needed for all information transfers, with relatively simple installation.

4.8.1 Eutelsat

EUTELSAT was originally a European consortium formed for satellite telephony. To be a member, it was required that a country be sovereign, European, and a member of ITU. Now it is a commercial operation with subsidiaries in USA and South America.

Eutelsat offers common specifications, ensuring total network interconnectivity and interoperability in a "Standard Network" in which earth stations characteristics and the satellite transmission parameters are specified. A variety of services are offered in the different areas. The "maritime broadband" service is offered from four satellites, W1, W2, W3A and Atlantic Bird™ 3. Other services from other of the totally 23 satellites may probably also be used.

Table 4-10 Eutelsat properties

Satellites	4 satellites covering different geographical regions (see below)
Transfer Mode	Packet switched
Frequency Band	Ku and C (Atlantic Bird™ 3)
Bit Rate	64 kbps to 2 Mbps, asymmetrically and with different service quality.
Coverage	Selected areas (see below)
User Terminal	VSAT terminal
Applications	Ship to shore link via stabilised VSAT terminal.

Coverage maps can be found on the www.eutelsat.com web page. They are not repeated here. Coverage for the above four satellites are Europe and the waters near European coasts as well as the Mediterranean. They also give coverage over parts of the Near East, including Red Sea and also the areas near Madagascar. Other satellites in the Eutelsat range, offer similar services, cover other area. Eutelsat does not in general provide coverage on high seas.

4.8.2 Intelsat

Intelsat is a global communications company providing Internet, broadcast, corporate network, telephony and hybrid space/terrestrial solutions around the globe via capacity on over 20 satellites.

They have a wide range of services, dependent on equipment and satellites.

Table 4-11 Intelsat properties

Satellites	20 satellites covering different geographical regions
Transfer Mode	Packet switched
Frequency Band	Ku and C
Bit Rate	64 kbps to 15 Mbps, asymmetrically and with different service quality.
Coverage	Most land areas and sea areas close to land.
User Terminal	VSAT terminal
Applications	Ship to shore link via stabilised VSAT terminal.

Coverage maps can be got from www.intelsat.com. Note also that Broadband Maritime is offering an "integrated service" over Intelsat with global coverage. The coverage map is shown in the Figure 4-5 (http://www.broadbandmaritime.com/).

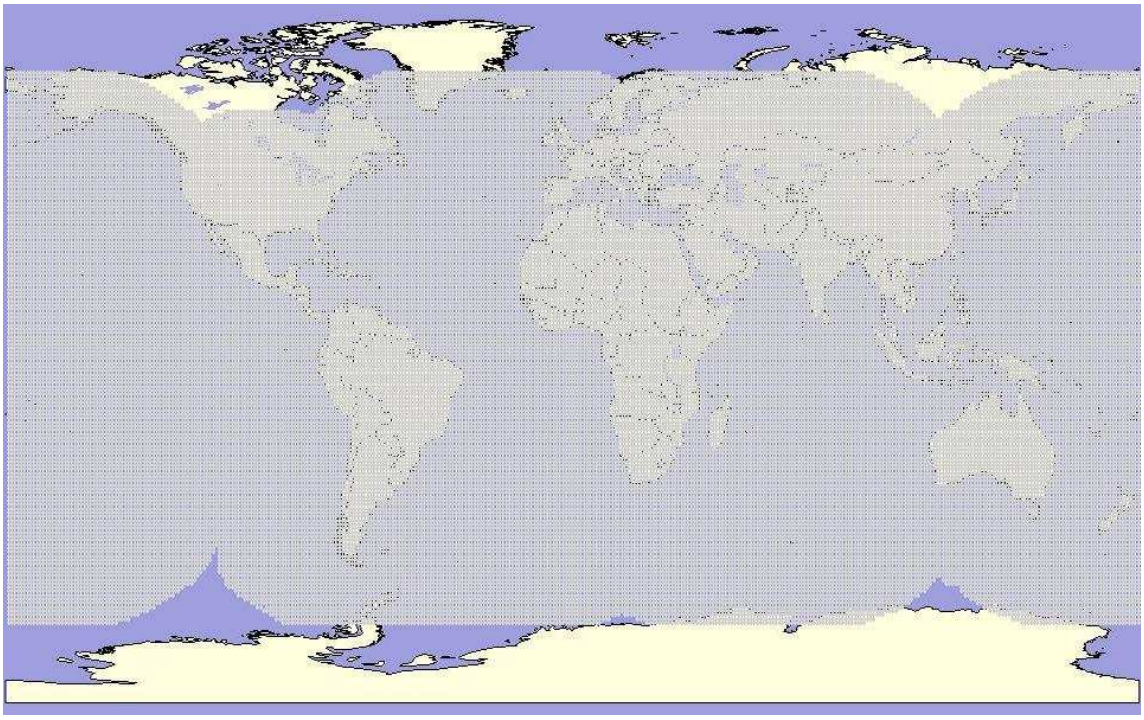

Figure 4-5 Intelsat coverage according to Broadband Maritime

4.8.3 Other VSAT systems

There are a number of other VSAT systems, but it is not clear to what degree these are generally used in the maritime area. Some examples of systems are listed below.

Table 4-12 Some other VSAT systems

System	# VSAT	Ref.
Europe*Star	2	http://www.europestar.com/
New Skies/NSS	2	http://www.newskies.com/
Satmex	2	http://www.satmex.com
Spacecom / AMOS	1	http://www.amos-spacecom.com

4.9 Other satellite systems

4.9.1 EGNOS

EGNOS is not a communication system, but is included here for completeness. It transmits correction signals for GPS and GLONASS systems via Inmarsat satellites.

4.9.2 ARGOS

ARGOS (Advanced Research and Global Observation Satellite) is a polar orbiting system of minimum two satellites that have general up and down link capacity for telemetry. It is among other things used for the ship security alert system and for ship tracking. Messages from the ship can be up to 32 bytes long, messages to the ship 16 bytes long (128 bits). Due to only two satellites being active and need to retransmit, one can normally not expect a very high throughput in terms of messages per time unit. Thus, the system is not useful for general communication.

The satellite operates in a 450 miles high orbit and can make use of low power and low footprint ground transmitters, e.g., for animal tracking [ARGOS].

4.9.3 GALILEO

GALILEO is not really a communication satellite and is only included here for reference. It will have a limited data reception facility that is compatible with COSPAS/SARSAT and intended used for the same purpose: To receive emergency beacon signals [GALILEO].

It has been discussed to add a short messaging service (SMS) to GALILEO, but currently it looks as if this will most likely not be done.

5 Integrated Services Solutions

Many VSAT services are sold via independent service providers, leasing satellite capacity. This section describes a few of these operators. The operators will typically provide a more or less turnkey solution for ship to shore communication and possibly also onboard services.

5.1 General satellite communication

5.1.1 Broadband Maritime

Broadband Maritime (see http://www.broadbandmaritime.com) is cooperation between several large actors in the maritime industry. They use the Intelsat satellites to provide worldwide coverage, comparable to Inmarsat. The system offers voice and data (over standard Ethernet) with combined bandwidths from 64 kbps (minimum) up to 1 mbps.

5.1.2 SeaLink

SeaLink is Telenor VSAT service suite of digital high-speed communications products that provide fully managed, turnkey solutions designed to extend corporate networks and make other broadband communications available on a leased basis to ships at sea. Examples of services are:

- IT services;
- On Board Telephony;
- Broadband Internet access;
- Entertainment services;
- Video communications;
- Remote monitoring & diagnostics.

The service is based on Intelsat and possibly other GEO systems. It provides up to 2 Mbit data speeds (dependent on satellite system).

5.1.3 Connexion by Boeing

Boeing is making broadband connectivity by 802.11b protocol (Wi-Fi) available for passengers and crew on selected airlines. The system uses satellite connection by Eutelsat. The same service is now being offered for maritime users. Currently the coverage is mainly limited to the North Atlantic, however extensions are scheduled. Connexion offers 20 MB maximum for download and 1Mb for upload.

5.1.4 Maritime Telecommunications Network

Maritime Telecommunications Network (MTN - http://www.mtnsat.com/) seems to be the largest operator on integrated communication systems to passenger vessels. They seem to use the Intelsat VSAT system, although other systems may also be in use. They have equipped most large passengers hips with their systems.

5.1.5 Globe Wireless

Globe Wireless (http://www.globewireless.com) provides a combined service from a HF digital network, Iridium and Inmarsat. They are operating the HF network themselves. Systems onboard will automatically select the most cost effective mechanism. The system is also approved for ship security alert (SSA) functions.

5.2 GSM networks onboard

Several companies offer GSM solutions for use onboard ships with VSAT links to shore and roaming agreements with other GSM operators. Some of these with known installations are listed below.

5.2.1 Maritime Communication Partner

Maritime Communication partner AS (http://www.mcpinc.biz/, [MCP]) is a Norwegian company with installations on at least 11 ships. They also offer CDMA support for use on US vessels.

5.2.2 Satpoint

Satpoint AB (http://www.satpoint.se/, [SATPOINT]) also provides GSM services in the same manner as the previous company.

5.3 Positioning services

5.3.1 PurpleFinder

PurpleFinder (www.purplefinder.com) provides an integrated tracking service based on periodic transmissions from the ship or any other asset via Inmarsat, GSM or other mechanisms. The ship position and other information can be retrieved from the company's web pages.

5.3.2 Ship@Sight

This is another positioning and tracking service provided by Radio Holland. It integrates SSAS functionality with an online web based ship tracking service (http://www.dirkzwager.com/product-safety-ssas.cfm).

6 Wire based communication

This chapter discusses various wire based communication systems. Most of these are intended for internal ship use, but also the issue of fixed link ship-shore communication is briefly discussed in 6.1. The issue of port internal communication is briefly discussed in 6.2. The sections thereafter will discuss various types of wire based network types. The discussion will mainly focus on functionality, as there are a wide range of protocols and technology to choose between. References to the most common protocols are made when appropriate.

6.1 General ship-shore communication

Most ship shore communication can be expected to be over wireless network or satellite, but ships with scheduled and regular arrivals or long stays in certain ports may opt for a fixed line connection. One can roughly divide wire bound ship to shore communication systems into two categories:

- *Over public telephone*. This includes ISDN and DSL type services and only requires a normal telephone twisted wire connection;
- *Direct Internet*. This is typically via unshieldet twisted pair cables (UTP) to a backbone with 10, 100 or 1000 mbps capacity.

From a practical point of view one can probably expect that WLAN or UTMS type connections will be preferred to these, as it involves no direct wires. However, the systems are briefly discussed below.

6.1.1 ISDN

Integrated Services Digital Network (ISDN) is a completely digital telephone/ telecommunications network for carrying voice, data, images, and video at high speed by sending digitally encoded signals. ISDN provides "end-to-end" digital service and can work on the copper wiring phone lines that are in most homes and businesses today. It typically offers 64 or 128 kbps over a circuit switched connection. ISDN requires the use of special ISDN telephones for voice communication. With one line, one normally has two channels of 64 kbps where each can be used for voice and/or data or combined [COMMAN].

6.1.2 DSL and ADSL

DSL (Digital Subscriber Line) and ADSL (Asymmetric DSL) allow high-speed digital communication over standard telephone cables. A special modem is required and support for DSL in the telephone exchange. ADSL can easily supply speeds up to 4 mbps to the subscriber and 1 mbps from the subscriber. A wide range of other speeds is available, depending somewhat on the quality of the telephone lines. DSL does not interfere with normal analogue use of the telephone line.

6.1.3 Direct Internet connection

This requires a twisted pair cable connection to the ship network/gateway and gives access to the port’s public network. Such a network can also be used for voice via Voice over IP technology.

6.2 Port area communication

For communication within a port area, one can probably assume that most is based on Ethernet and Internet protocols. However, some systems may use special technology, in particular video (for surveillance) and voice for communication. Also some access control networks may use special protocols of the type discussed in following sections. A brief overview of some possible network types is tabulated below.

Table 6-1 Some communication types in port

Communication type	Technology	Access
Ship nautical supervision	Radar, AIS	N
Ship communication	HF, GSM, Sat	N
Ship IP services over WiFi (or cable)	WLAN	O
Communication to mobile units/patrols	HF, GSM	S
Access control, supervision, patrols	IP, FB, PR	S
CCTV	IP, PR	S
Cargo supervision	IP, FB, PR	B
Logistics and resource management	IP	B
Cargo registration, RFID	IP, PR	B
Reports, office applications, interface to other systems	IP, EDI, Fax	B

The technology column lists possible types of networks, where the following abbreviations are used:

- *Radar, AIS, GSM, WLAN*: As normally interpreted;
- *Sat*: Satellite, VSAT or INMARSAT;
- *HF*: UHF or VHF radio;
- *IP*: Internet Protocol and Ethernet based networks;
- *FB*: Fieldbus type networks (see ship network section for examples);
- *PR*: Proprietary networks.

The access column indicates what type of use is made of the data. The following codes are used:

- *N:* Nautical, ship management and supervision. This may also include transmission of local differential GPS signals and other information related to ship nautical operations;
- *O:* Open access, services to users. This is a general service to ships and other mobile units that is in operation, e.g., in Amsterdam and four Finish ports [RN04];
- *S:* Safety and security. This is services related to supervision of port safety and security;
- *B:* Port business related. This is services related to the commercial operation in the port. In this group are also all services related to ship-port reporting and general communication.

This is just an indication of the communication services in a port. Note in particular that the last table entry is a catch all for services that also include ship-port information exchanges. From the perspective of WP2.2, this is a general service that most likely will be available over Internet and other digital channels.

Also, from the perspective of the mobile islands network, it is probably the way the ship establishes communication to the general Internet that is of interest. This has been discussed in the preceding section.

6.3 Network layers

Ship (and other systems) network are generally organised in a tree structure. This is a robust and convenient structure as it reduces interference between networks to a minimum.

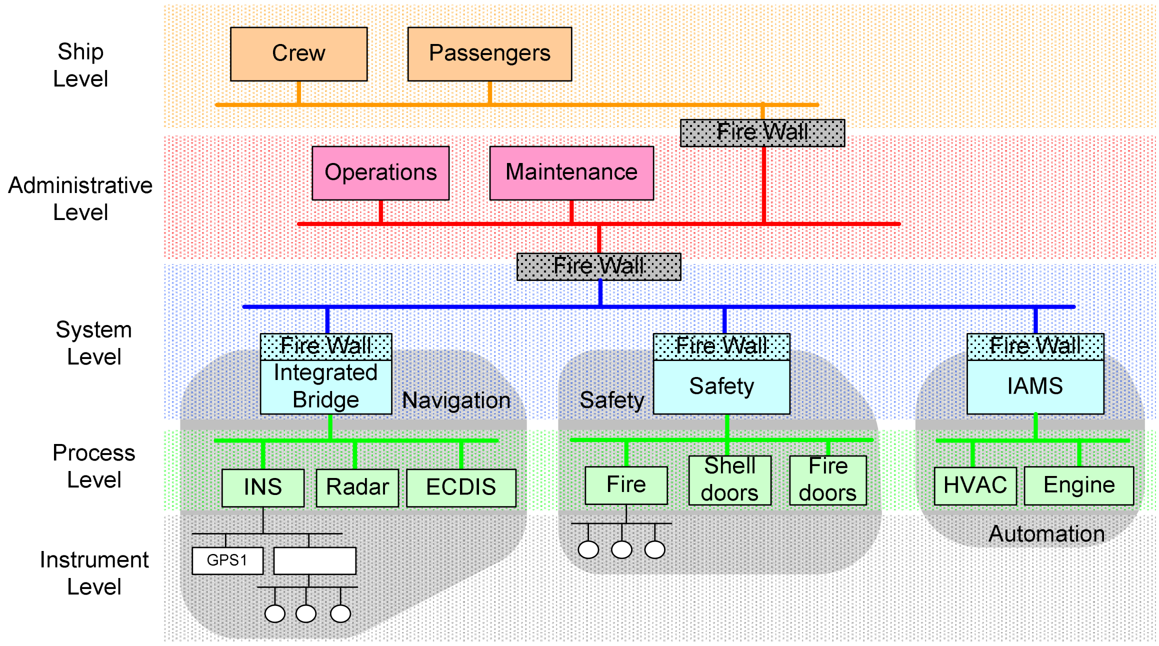

Figure 6-1 Layered ship network

In Figure 6-1, a possible structure for a ship network is illustrated. On the lowest level is a number of "instrument networks" that interconnect low level devices, e.g., GPS receivers, heading sensors and so on. On the level above this, a number of "process networks" interconnect devices and computers related to one process onboard. In this figure, the navigation or bridge system is shown as one process, the safety systems as one and the Integrated Alarm and Monitoring Systems (IAMS) as a third. The latter will typically include engine control as well as heat and ventilation control. On the next level is a system level network interconnecting the different process segments to achieve integrated ship control. As an example, alarms from fire alarm systems must be transferred to the IAMS and fire alarms might also trigger specific smoke extraction functions in the ventilation system. This layer is mostly implemented as point-to-point links today. On the next level is the technical and operational functions collected on the administrative or ship office network. This may again be connected to a ship level network.

Note the use of "firewalls" between process networks and between higher layers. The purpose of these firewalls is twofold:

- Ensure that faults or malicius actions in one network segment cannot influence others. This includes limiting the number ond frequency of external access requests to a safe level. This is in particular critical for the process networks;
- Ensure that data only is made available to authorised users. This is not directly safety related, but covers protection of sensitive commercial or personal information.

Note also that firewalls may be embedded in parts of the system or in the communication means used. As an example, a talker type serial line protocol (IEC 61162-1 – see below) can transport data from one system to another while ensuring that no problem in the second system propagates back to the first.

Different ships will show different topologies and one cannot normally expect to find a pure tree structure in all cases. However from the instrument level to the gateway to the administrative or ship level networks, one will normally employ a very strict tree structure to ensure integrity in the different functions and to ensure that faults in one process or in one network propagate to others.

Today, most of these networks are decoupled to maintain safety and robustness. Some integration takes place, but this is very limited and usually just to connect one system to another through a point-to-point serial link. Some systems also allow remote access through an Ethernet gateway, typically via use of virtual private network (VPN) technology. Thus, the figure more indicates a principle than an actual realization.

6.4 Safety related networks

Several networks are installed on the ship to transport safety related information. The use and installation of these networks will in most cases be regulated by IMO, flag state and class society regulations. The Table 3-1gives a summary of some of these networks and the following sections will go through them in some more detail.

Table 6-2 Summary of some safety related networks

Communication type	Technology	Layer	IP
Wireless UHF	UHF radio	S	VoIP/WLAN
Navigational instruments	IEC 61162	I	
Integrated bridge	PR	P	PR/IEC 61162
Public announcement	PT	I	VoIP
Fire alarm loops	PR	I	
Fire system integration	PR/FB	P	PR/FB
Fire protection equipment	PR/FB	I	
CCTV	PR/Open	P	PR/Open
Intruder alarm	PR	I	
Shell and watertight doors	PR/FB	I	
Internal voice communication (dedicated)	PR	I	
Automation field bus	PR/FB	I	
Engine control, IAMS	PR/FB	P/S	PR/FB
Tank and ballast instrumentation	PR/FB	I	
Tank and ballast control	PR/FB	P/S	PR/FB
Bilge water level detection	PR/FB	I	
Cargo monitoring and control	PR/FB	I/P/S	PR/FB
HVAC	PR/FB	I/P/S	PR/FB
Fresh water	PR/FB	I/P/S	PR/FB
Black water/grey water	PR/FB	I/P/S	PR/FB

The table also indicates type of technology typically used as for Table 6-1. The "layer" column specifies the typical network layer as defined in Figure 6-1. The codes used are I – Instrument, P – Process, S – System, A – Administrative and O – Open ship level. The last column specifies if it is likely that the communication can use IP protocols, potentially via a ship wide integrated network.

6.4.1 Onboard safety communication

Ships are required to have an onboard communication system, typically based on UHF "walkie-talkies". This is not wired technology, but is included here for completeness. On can in principle also implement such systems over WLAN and voice over IP technology.

6.4.2 Navigational instruments

Navigational instruments are normally interconnected with the well-established IEC 61162-1 or IEC 61162-2 standards. These are based on standard asynchronous serial lines with a text message protocol. Communication speeds vary from 4.8 kbps (IEC 61162-1) up to 38.4 kbps (IEC 61162-2).

The network uses a single talker and a number of listeners in a star shaped configuration. Each line is unidirectional. Message-length is maximum about 80 characters and maximum message rates will depend on actual line speed.

The standard is also referred to as NMEA 0183 [NMEA 0183] as that is the basis for the IEC produced specification. However, for SOLAS certified ships, the correct reference to use is IEC 61162.

A CAN (Controller area network) based bus solution is also under development in IEC [IEC61162-3]. This will be based on [NMEA2000]. This system will allow up to about 50 nodes to share a common bus at 250 kbps. Messages vary from 8 bytes up to about 1000, but at an overhead of 50%. Thus, effective maximum throughput on the bus is about 125 kbps. Note also that this capacity has to be shared between all bus users.

The IEC variant of NMEA 2000 will require full redundancy and has, in cooperation with NMEA, decided on mechanisms to facilitate this.

"Navigational instruments" need to be interconnected both on the bridge and in other ship locations. Typically will interfaces to steering and some engine control facilities fall into this category.

6.4.3 Integrated bridge systems

The [IEC61662-4] standard was developed in the 4FP EU-project PISCES [PISCES]. The specifications was accepted as an international standard in 2004, but has not yet been implemented in production quality code. It is based on a dual Ethernet using IP protocols on lower levels. The high level protocol (application profile) is specific to this specification. It can also in principle run on a single Ethernet, but cannot be used for safety related applications in such a configuration.

The IEC standard was developed mainly for navigational system integration, but can in principle be used for all ship systems. Its functionality is similar to OPC [OPC], but it provides better functionality for redundancy and "exception handling", i.e., detection of bad or lost connections, loss of redundancy and recover after connection loss.

The standard was based on the earlier MiTS (Maritime Information technology Standard) [MiTS] that has been implemented in a relatively small number of ships (probably less than 50 all together).

6.4.4 Public announcement

Public announcement (or PA) systems are safety critical systems with special requirements for implementation and cabling. Requirements are similar to those for fire alarm systems. This means that PA networks, that span the whole ship, usually are implemented as dedicated networks.

PA networks are today usually implemented as analogue voice networks. However, also in this segment is Voice over IP starting to be used.

6.4.5 Fire alarm systems

Fire alarm systems will normally employ a two-layer structure: The lowest level is the fire detector loops with usually proprietary networking technology. The higher layer can, if need be, integrate different components of a large fire alarm system, e.g., by integrating detection systems in each main fire zone.

A fire alarm system will in many cases also supervise and control fire protection equipment such as fire doors, fire dampers and extinguishing systems. This may also include reporting points for fire patrols. However, such systems may also have a dedicated controller, in which case typical instrument network systems are used to interconnect them.

6.4.6 CCTV

The camera surveillance systems will normally use a video based coaxial network to send camera signals to a central. However, it is more and more common to use IP based protocols and an Ethernet network also for this purpose. Some manufactures also integrate a full web server in their cameras so that it can be hooked up to a wired or wireless Internet connection without special equipment or software [WB11A].

6.4.7 Access control and security

In most passenger ships, access control is done with the same technology as is used in passenger and crew cabins. These systems do not normally use networks, but rely on special protocols between door locks and key cards.

In some cases, perimeter watch or intruder alarm systems may be installed to alarm crew when authorized or unauthorised persons visit certain areas. Such systems will in most cases use proprietary instrument level network types.

6.4.8 Shell and watertight doors

Shell doors and watertight doors are normally controlled by separate systems with its own network for collecting information from the respective doors. This is either a field bus type network or another proprietary instrument level network.

6.4.9 Internal voice communication

There are various IMO regulations requiring communication facilities on the ship, e.g., between emergency steering position and bridge and between engine room and bridge. Also the access to wireless UHF "walkie-talkies" will in most cases require a spreader network to provide access over the whole ship. These networks are usually analogue and of a dedicated type that do not lend itself to other use.

In the future one could imagine that also this communication was carried over, e.g., wireless digital communication links, provided that the system satisfied relevant functional and safety requirements.

One could also in principle use the normal telephone system for this purpose, but some requirements for direct and dedicated links makes this a bit complicated.

6.4.10 Engine automation equipment, integrated alarm and monitoring

Most ships are equipped with a digital engine control system. This is a relatively complex system that allows multiple control positions (e.g., bridge and engine control room) as well as distributed direct control of equipment. Modern systems will typically be built with a set of instrument networks for direct control and monitoring and a higher level process network for distributed control stations.

This system will in many cases be the same as the integrated alarm and monitoring system (IAMS) that also supervise parts of other processes than power generation and propulsion.

Note that an IAMS may also integrate control functions for some systems, although many systems as, e.g., HVAC, retain a separate network with only alarms transferred to the IAMS.

6.4.11 Cargo and ballast control

Cargo control networks are required on liquid cargo bulk carriers to monitor and control tank levels. Likewise, ballast control systems are required on all ships. Also, for certain ship types, there is a need to supervise void spaces for water ingress.

Cargo and ballast control is typically implemented as a separate system, but can in principle be part of an integrated control system. The system will most commonly be implemented on dedicated instrumentation networks, but may use a higher-level process network for multiple workstations.

Bilge water level monitoring is often part of the general automation system, but may also be a separate system.

Other ships with special cargo may also have dedicated systems for monitoring of the cargo. A typical example is a reefer ship that needs to monitor and control the cooling systems. Also liquid petrol or natural gas (LNG/LPG) carriers require advanced cargo control systems.

Inert gas generation for tankers also require some monitoring and control. This can be included in fire protection equipment control or in the general alarm system. The same is the case for special monitoring systems required when certain other types of dangerous cargo is carried.

6.4.12 Life support systems

Living conditions and “life support systems” are obviously important, but may be critical on ships with many persons onboard, particularly when operating in either very hot or very cold climates. With the growing emphasis on the passenger ship as its own lifeboat, life support systems will also get increasingly higher attention.

Heat, Ventilation and Air Condition (HVAC) can thus be looked at as a safety related system. HVAC control systems cover most of the ship and use digital control and monitoring facilities. It will typically employ a mix of different network types, dependent on manufacturer. High-level control may be from dedicated control stations or from the integrated control system.

Likewise, the maintenance of fresh water generation and black water (sewage) processing can be critical on ships with many persons onboard. With increasing demands on environmental friendliness, these systems are now becoming very complex and have correspondingly complex digital monitoring and control systems.

6.5 Operation and business related networks

In addition to safety related networks, the ship will also have a number of other networks that are used for more operational tasks, e.g., internal and external communication and administrative tasks.

Although the networks are not safety related, they may be critical for efficient and economical operation of the ship.

Table 6-3 Summary of some operation related networks

Communication type	Technology	Layer	IP
Telephone	Analogue	O	VoIP
Wireless telephone	PR	O	VoIP/WLAN
Ship office network	IP	A	IP
Cargo monitoring	IP	A	IP
Ship access	IP/PR	A	IP/PR
Mini-bar access	IP/PR	A	IP/PR
Pay movie	IP/PR	O	IP/PR
Point of sales terminals	IP/PR	A	IP/PR

Table 6-3 gives an overview of these networks in the same format as in Table 6-2.

6.5.1 Telephone

For convenience, almost all ships have an internal telephone system. This is based on standard technology on the landside, normally based on analogue transmission and dedicated switches. However, Voice over IP (VOIP) technology is likely to be introduced here also, at least in a longer perspective.

Note that the telephone system normally also is available for passengers and thus defines it as being on the open ship level in the network hierarchy.

6.5.2 Wireless telephone

Some ships, typically larger passenger ships, will install a wireless telephone system integrated with and in addition to the fixed telephone. This is typically based on DECT technology, but could also use WLAN and voice over IP technology. Although not a wired system, it is included here for completeness.

6.5.3 Ship office network

There is an ever-increasing amount of administrative work on a modern ship. This requires office computers and networks. Networks are normally standard Ethernet/IP type networks. They may be limited to the ship offices, but can also extend into other areas, e.g., officers' cabins etc.

6.5.4 Cargo monitoring

Container ships will in some cases implement networks to collect information from cargo containers. This information may be used onboard or sent to shore. The monitoring is typically not safety related, but has implication for the transport quality and general business. One can expect that such networks also are IP based.

6.5.5 Critical passenger services

Certain services to passengers can be looked as business critical as failures may seriously impact how passengers view the quality of operation or otherwise seriously impact efficiency of operations. Examples of this may be cabin access control systems, ship access systems and similar. Access control to cabins is mainly a distributed system with no communication between cabins and the central control system. The same is typically the case for in-room safes. However, Ship access control however need to match passengers with current passenger lists and needs to be on-line.

To a certain degree, one may also put information and entertainment services into this category, but these are described in the next main section.

6.5.6 Mini-bar network

Modern passenger ships have mini-bar systems that are on-line to register removal of articles as soon as it is made. This is partly used for automatic charging, but also for general customer and product management. Systems will typically interface to existing Ethernet networks and are controlled by a central workstation.

6.5.7 Pay movie

Most passenger ships offer movies for payment via in cabin TV sets. Communication to and from the central controller is normally via the TV coaxial cable, using proprietary communication protocols. However, also here is IP based transmission of video and control signals becoming a possibility.

6.5.8 Point of sales networks

Point of sales terminals and collection of payment information from passengers is also a critical function for passenger ship business. This also includes systems for inventory management in shops and similar systems. One can expect that this is based on IP type technology in combination with more proprietary solutions for interfacing smaller terminals to the network. Some ships, for instance Cunard's Queen Mary II, also use WLAN technology for the terminals [IG04].

6.6 Communication and entertainment networks

The third class of networks is composed services not directly linked to safety or core business. Telephone systems could have been put in this category, but have already been discussed in the previous group.

One should note that some of the below services in most cases are based on payment and, thus perhaps should be put in the previous class. Also, even free services may be critical in terms of passenger satisfaction and may for that reason be included in business critical services.

Table 6-4 Summary of some non-critical networks

Communication type	Technology	Layer	IP
Crew and passenger Internet	IP	O	IP
Television and radio	Analogue	O	IP
GSM	GSM	O	

6.6.1 Crew and passenger Internet

Internet access for crew and passenger is becoming more and more common, either as wireless networks over WiFi, as standard plug in the wall or as dedicated workstations. The system is based on standard IP networks and protocols with some additional software mechanism to control payment.

6.6.2 Television and radio

Television and radio is closely linked to pay movie access, but is repeated here for completeness. Old systems may use general video distribution over coaxial cable. Such systems can easily be exchanged with Internet protocol based solutions.

6.6.3 GSM

Some companies are already providing general GSM services onboard of passenger ships [SATPOINT, MCP]. This allows passengers to use their ordinary GSM telephones in a network that basically works as any other international network with roaming agreements. The technology is based on the use of standard GSM stations, but is typically using a VSAT channel for transmission of data to and from land.

It is interesting to consider using this type of GSM network also for business critical or even safety critical applications onboard. This would require a more robust network, but should not pose any real technical problems.

As has been noted elsewhere, the ability to have wireless digital access on the ship for safety and operational purposes could be a significant benefit. GSM could provide a robust and well-proven solution for this, based on standard off the shelf technology. As such, it is a possible alternative to a wireless LAN on the ship. Benefits of GSM are a more mature technology and possibly better transmission properties in a ship (possibly more robust against multi path distortion and better penetration). Hand held terminals would also be readily and cheaply available in different forms.

7 Ship communication uses

[SWAN] contains an analysis of required applications that are included in the applications described in the following sections. Additional applications have been collected from other sources that are referenced where applicable.

The first section gives a summary of all listed applications with characteristic parameters listed. Following sections give a more detailed description of the applications, divided into a number of main groups.

7.1 Overview of communication related applications

The Table 7-1summarises the applications that are dependent on communications to work. Following section gives a short overview of the communication types. The first column gives the application name as found in the below sections.

The second column specifies the ship type most applicable for the application. Codes used are:

- ‘S’ – Required for all SOLAS ships (‘s’ – lower case – for possible future legislation);
- ‘F’ – Fishing boats;
- ‘P’ – Passenger ships.

The following group of columns specify what service is required for the applications. The title of the column should give a reasonable understanding of what is means. Small message is a few kilobytes of text or other digital information; large messages are likewise larger messages (tens of kilobytes) with digital information or text. Voice is analogue or digital voice and video is still pictures or streaming video.

The next column indicates the bandwidth requirements. This is more or less given by the preceding type of traffic. Empty means very low to low and that it can be handled via dedicated systems. Other codes are:

- ‘L’ - low bandwidth, but that messages in most cases should be transmitted as a digital message;
- ‘M’ - medium bandwidth is required. This can be interpreted as between 9.6 and 64 kbps or direct voice communication;
- ‘H’ means high bandwidth and can be interpreted as about 64 kbps or higher, this includes ability to transfer still images;
- ‘V’ means multi-media enabled very high bandwidth, typically at 1 mbps or higher.

The following column specifies if the service uses a mandatory carrier system. The codes used are:

- ‘A’ – AIS carrier on VHF;
- ‘I’ – Radio or INMARSAT carried.

The next column specifies if communication is required from the ship itself (alternatives are, e.g., that the owners or manager’s office sends the information):

- ‘H’ - communication may be necessary even at high seas;
- ‘C’ - communication is only required near coast;
- ‘P’ - communication is only required close to or inside ports.

The “Mode” column specifies direction of data, if not bi-directional direct communication:

- ‘B’ - communication can be sent as broadcast to a range of ships;
- ‘M’ – Store and forward, mostly from ship (e-mail);
- ‘S’ - information is only transmitted from ship.

Table 7-1 Overview of communication uses and classification

	Ship type	Small message	Large message	Voice	Video	Bandwidth req.	Dedicated carrier	Ship direct com.	Mode	Sensitive info.
AIS	S	X					A	H	S	
DSC and SSAS	S	X					I	H	S	S
NAVTEX, SafetyNet	S	X					I	H	B	S
Blue box	F	X						H	S	L
General radio	S			X		M	I	H		S
Weather data			X			H		H	B	S
SAR Communication	S			X		M	I	H		S
Other required applications	S	X		X				H		S
LRIT	s	X				L		H	S	S
IMO FAL reports	S		X			L			M	L
Port state reports	S		X			M			M	L
NVMS	S		X			L			M	L
AMVER and related		X				L		H	M	
Ship operation/administration			X	X		L		H	M	PC
Engineers support			X	X	X	M		H		C
Passenger management			X	X		M		C		PC
Chart updates	S		X			H			B	SC
Emergency management			X	X	X	H		H		S
Telemedicine			X	X	X	H		H		S
Special data			X	X	X	V		H		C
Port planning			X			M				C
Port information systems				X	X	V		P	B	
Crew communication			X	X	X	H		H		P
Passenger communication	P		X	X	X	H		H		P
Passenger entertainment	P		X	X	X	V		H	B	

The rightmost column specifies if information is particularly sensitive:

- ‘C’ - there are commercial interests that require encryption/acknowledgements;
- ‘P’ - it is private communication that require special handling;
- ‘L’ - information required by legislation;
- ‘S’ - it is safety related information.

Note that although the table lists messages related to the ship, the ships owner or agent may send many of these messages. This is particularly the case for messages related to ship arrival notifications.

7.2 Mandatory applications

SOLAS requires a number of communication systems to ensure safety of the ship and its crew. Most of these regulations are contained in SOLAS Ch. IV, Radio communications. The following sub-sections discuss these systems in groups related to their general communication system usage.

All the SOLAS requirements can be satisfied without systems for general-purpose digital communication. Ships are not even required to be fitted with INMARSAT radio, even when operating in A3 areas.

However, the developments in SOLAS have firmly established INMARSAT as the preferred system for safety related ship shore communication. For many ships, the INMARSAT terminal will also be used for other types of communication as described below. After the privatization of INMARSAT in 1999, IMO is also working on systems to extend the preferred status of INMARSAT to other commercial operators.

7.2.1 AIS

AIS uses a communication channel that is not generally available for communication beyond positional reports. However, it is included as a separate group due to its importance for the MarNIS project.

7.2.2 DSC and SSAS

The ability to automatically transmit identity and position via satellite or radio is used in GMDSS and SSAS. This is an on demand service. The ship is required both to listen and to be able to send such messages. EPIRB systems operating over Inmarsat can also be put into this group.

7.2.3 NAVTEX and SafetyNet

These are medium sized messages containing important messages to navigators. This is typically storm warnings, iceberg warnings or other dangers to navigation. Also some rescue related data is transmitted via this system.

7.2.4 Blue box - VMS

New European (and also other countries’) legislation for fishing boats require them to have a “blue box” onboard. This shall “continuously” provide information about position and other data that makes it easier to enforce fishing related legislation. See also section 3.1.6.

7.2.5 General radio

Ships are required to have communication means available for bridge to bridge and bridge to shore communication. This will in many cases be VHF and HF radio, but is more and more frequently implemented as INMARSAT radio. All radio communication will normally support ship identification messages through DSC or equivalent systems.

7.2.6 Weather information

Ships are required to consider weather information and that can be done with a weather fax over HF or MF (next section). However, more detailed weather information, as digital data that can be used in route planning requires relatively large amounts of data.

7.2.7 SAR communication

Ships must be able to communicate with SAR centres (MRCC), on scene commanders (e.g. coast guard or designated other ship) and other ships in an emergency area. This applies both when the ship itself or other ships are in danger. Communication is today based on voice radio, but there is a significant potential in using digital exchange of data in such settings. Simple examples are transmission of video images for damage assessment and passenger lists for evacuation.

Note that passenger ships in fixed routes are required to establish formal relations with SAR/MRCC along the normal route. Note also that communication with SAR also is supplemented with communication to emergency coordination centres at the owners or operators office and between that office and SAR [DSS_DC].

7.2.8 Other required applications

Other mandatory applications are based on use of automatic equipment or equipment with dedicated functionality, not normally used for other communication purposes. Examples of these are general EPIRB, radar and radar transponders. These systems are used to send and/or detect information on location and speed vector of ships.

Also short-range general radio-communication is included in this group, such as bridge-to-bridge communication over VHF radio and hand-held emergency communication systems.

Weather fax is also included here.

7.3 Mandatory or public reporting

From IMO, the SOLAS Convention is the most important of all international treaties concerning the safety of merchant ships. The SOLAS Convention specifies minimum standards for the construction, equipment and operation of ships, compatible with their safety. Flag States are responsible for ensuring that ships under their flag comply with its requirements, and a number of certificates are prescribed in the Convention as proof that this has been done. Control provisions also allow Contracting Governments to inspect ships of other Contracting States if there are clear grounds for believing that the ship and its equipment do not substantially comply with the requirements of the Convention - this procedure is known as port State control. The current SOLAS Convention includes Articles setting out general obligations, amendment procedure.

SOLAS mandates a number of reports that are required from the ship or the ships agent related to the passage through controlled waters or arrival to or departure from ports.

There are also other systems that are not directly mandatory that anyhow postulates that report should be sent from the ship to shore.

7.3.1 LRIT

Long Range Identification and Tracking is not yet defined in IMO, but there is continuous work going on in this area. When and if finalised, it will most likely be based on a principle similar to DSC, but with extended reports and more frequent updates (possibly every four hours). One can expect that INMARSAT will be one allowed method for reporting LRIT coordinates.

7.3.2 IMO FAL forms

SOLAS requires a number of reports to be sent from ship to shore before a port visit, when entering VTS areas, after an incident at sea or in other situations. The actual messages that are required will not be discussed here, they will be analysed and systemized by cluster 1 in MarNIS.

7.3.3 Mandatory ship reporting

Ships of certain types that are entering a number of predefined and IMO accepted ship reporting requirements are required to transmit certain information to designated control centres when entering the ship reporting areas. The messages can typically be sent via e-mail, fax, INMARSAT or other means. If sent as text, the messages have a standard format defined by IMO.

7.3.4 Port state reports

The port state and its authorities (immigration, customs, agriculture etc.) will require a large number of reports to clear the ship and its cargo for arrival. This issue is handled in MarNIS cluster 1.

7.3.5 NVMS

The National Vessel Movement centre [NVMC] is operated by the US Coast Guard to maintain records of all ships entering US ports. It requires notification before entry with a fairly extensive reporting form. Reports may be submitted by fax or as Excel or XML files. It can be looked at as a variant of general port state reporting requirements and contain much of the same information as the IMO FAL forms.

7.3.6 AMVER, AMVER/SEAS and similar systems

Several systems, among them AMVER [AMVER], receive voluntary ship position reports and store these for use in the case of an emergency. AMVER was originally intended for the north Atlantic, but does today cover the whole world. AMVER currently has around 3000 vessels reporting each day from a total of around 12000 ships registered in the system.

AMVER uses simple text messages that are transmitted via e-mail. The carrier can be anything that allows e-mails to be transmitted to shore. The message format is the standard IMO reporting format.

The AMVER/SEAS program has also supplemented AMVER: whereby ships voluntary supplies metocean data to the National Oceanic and Atmospheric Administration (NOAA) to increase quality of weather forecasts. Only a few hundred ships participate in this service.

A similar service to AMVER/SEAS is also maintained by Olex AS in Norway [Olex]. This service collects depth data and makes it collectively available to all users of the system.

7.4 Commercial ship operation

7.4.1 Ship operation and administration

Typically performed by general-purpose e-mail with attachments, ship to ship and ship to shore. This can include trip/route planning and updating, crew related issues etc.

Standard reporting requirements are fuel consumption, travel details and other related data once each 24 hours (typically “noon at sea”). This also includes machinery reports when applicable.

The actual reporting requirements will vary with ship type and operation strategy. However, one can assume that a relatively low bandwidth is required.

7.4.2 Engineer’s support

This type of reporting can be assumed to become more common as operational strategies goes more towards shore based technical operation management.

This is mainly related to technical maintenance and operation and may include access to shore-based information services and company’s databases, interaction with shore-based company staff for, maintenance planning, remotely assisted problem solving and handling of immediate problems.

One may also want to use such services for direct access to safety critical equipment, either for diagnostics, maintenance reports or for repairs, e.g., update of configuration or software. The latter issue causes problems with typical class requirements that do not normally allow neither software nor configuration updates of installed equipment. However, this may be solved by suitable type approvals of update mechanisms and patches.

Access to safety related equipment also causes problems as such access in theory can endanger functionality of equipment self or other equipment connected to the same access network. These issues need to be considered before such functions are implemented.

7.4.3 Passenger ship management

Passenger ships will generally require much more interaction between ship and shore than other cargo ships, also when related to management. Typically, trips are relatively short and there is a lot of logistics issues regarding food, beverages and other issues related to the accommodation of passengers aboard.

Services in this category can also include on-line payments of services onboard or on shore, updates to cabin allocations etc.

7.4.4 Electronic chart updates

Electronic charts and notices to mariners need to be transferred to the ship to update onboard records. This can be done in port or near ports.

Note that this type of information normally is valid for a range of ships in a certain area and that broadcast type satellite transmissions may be an efficient way to distribute such information. However, it requires encryption to enable charging for the update services.

Another problem is that update of the ECDIS station requires that the data is transported to the station, possibly through the navigation network. This may require certain measures to guarantee integrity of system and that the transmission cannot endanger safety critical functions. This is similar to the same problem for "engineer's support".

7.4.5 Emergency management

Emergency management is ordinarily handled by radio and voice communication, but as has been shown in several projects, e.g., [DSS_DC], there are clear benefits to be had by combining digital message exchanges with video images and in general more extensive communication between ship and shore. This will in most cases require around 64 kbps communication links.

7.4.6 Telemedicine

Medical tele-consulting for crew/ passengers dealing with routine tasks and handling of emergency incidents - transmission of critical patient data, communications with shore based medical staff, consultation of shore based information resources, transmission/ reception of medical records, etc.

7.4.7 Special requirements

Some ships do special surveys and require higher transmission capacity to shore. This can include scientific surveys, oil exploration or many other types of ships. They will normally use VSAT technology for shore side transmissions.

7.5 Ship and port logistics

7.5.1 Port planning data

When a ship enters port, there is a host of messages that needs to be transmitted regarding various resource planning and logistics operations. Cluster 1 will in detail analyse the reporting requirements.

7.5.2 Port information system

More advanced port information system services can also be considered where, e.g., geographical information about location of resources, sailing plans etc. are transmitted. Such a service would probably be based on local wireless networks.

7.6 Infotainment

7.6.1 Crew personal communications

Personal crew communication via e-mail can be managed on a communication link with fairly limited bandwidth. However, for web browsing, news reading and exchange of video and voice, higher bandwidth is necessary.

7.6.2 Passenger communications

Passenger communication can be expected to require much higher bandwidth than for crew; mainly due to the usually higher number of passengers and also because they often will be more willing to pay for such services. However, for small number of passengers one can make do with a normal 64 kbps line or so.

This also includes applications of mobile island networks and similar concepts where passengers get access to shore phone lines through cabins or mobile phones.

7.6.3 Passenger entertainment

For general web browsing, typically with multi-media content, one will require VSAT type communication with very high bandwidths.

In this category can also streaming video and vide on demand be put, although this most likely will require a combination of broadcast and a direct control link to work.

8 Information networks at sea and on shore

Broadband communication needs to be looked at in conjunction with the different established networks, both on ship and on shore, and the functions these networks have.

For off-ship networks most dedicated information networks can be reached through the Internet. Thus, it is obviously interesting to interface ships to the open Internet and through that to other dedicated networks. This is relevant for crew and passenger infotainment and for general access to most other resources for ship operation or safety, e.g., metocean data.

However, one must expect that bandwidth available for general Internet access will be limited also in the future and that the use of Internet possibly should be combined with dedicated broadcast services, e.g., for ENC, metocean or video.

8.1 Ship network

The ship itself has several onboard networks as was discussed in 3.6. It has been claimed that a modern cruise ship has more than 2000 km of communication cable onboard [HANSA09]. A also was pointed out in 3.7, it is an obvious need to interface some or most of these networks with the ship-shore communication links (see also references to COMMAND, DISC and PISCES projects), but there is also a need to integrate these networks so that relevant information can flow between them. Particularly for some new applications like automatic ENC updates, interactive emergency management and onboard engineers support, the communication between these networks and the shore side support systems will be critical.

8.2 The owner's network

Most ship owners and managers set up international networks to coordinate activities in different ports, offices and ships. This network will typically be of an intranet type, based on IP protocols. It will be relatively open once the firewalls and entry-level gateways have been passed.

A relevant question in the context of MarNIS is to what degree the ship level network should be integrated with the owner's network. Today this is sometimes the case for the ship office network when the ship has high bandwidth VSAT connection, but mostly commonly the ship network is mostly off line and uses store and forward type communication mechanisms either to synchronise databases or to exchange e-mail.

8.3 Authorities' networks for ship safety

European authorities have set up special purpose networks to handle some aspects of ship safety and security. A notable system is SafeSeaNet [SSN] that shall exchange information between port states to facilitate better control of ships and their cargo in European waters.

Also national authorities typically set up own networks to integrate VTS stations with each other and with SAR organisations. This will give significantly better information both to those that shall supervise traffic in national waters and those that are responsible for handling emergencies or incidents.

AMVER [AMVER] has also been mentioned as one network (database) that gives assistance in emergencies. Ships can on voluntary basis report voyage information to AMVER.

Ships are already indirectly integrated in SafeSeaNet through the VTS systems and the ships' use of AIS transponders. Cluster 1 in MarNIS will also investigate to what degree ships and other actors shall have access to the SafeSeaNet infrastructure. Also for SAR purposes, there is obviously a great potential for more efficient handling of emergencies through tighter integration.

8.4 Networks for ship quality assessment

The Equasis [Equasis] and SIReNac [SIRENAC] databases are other examples of "networks" that allow exchange of ship related information. These databases are most relevant for port state control officers and others that have an interest in "ship quality".

These networks will normally be accessed through a controlled gateway, either via specific users (e.g., port state authorities) or directly. It is probably not relevant to extend the network infrastructure as such beyond this. Also, the problem of interfacing to and making use of the information in these networks are handled by other parts of MarNIS.

8.5 Networks for immigration, customs and other authorities

Another type of network is the Schengen Information System (SIS) that allows immigration authorities to exchange information about people in side the Schengen area.

It will normally not be relevant to interface to these networks other than indirectly through direct users of the systems, e.g., customs or immigration authorities. Information in these networks is highly sensitive and will not normally allow any degree of open access.

8.6 Trans-European Service for Telematics between Administrations (TESTA)

TESTA (Trans European Services for Telematics between Administrations) network is the largest, of the 30, public service IT infrastructure projects funded by the European Commission. It provides a controlled communications environment for public administrations to exchange administrative information with a guaranteed quality of service. TESTA interconnects the European commission and national administrations across Europe in sectors such as justice and home affairs, health and consumer protection and statistics [TESTA].

9 Some relevant projects

This section describes projects that have been used as references in this document. It is mainly related to communication technology, but some application-oriented projects have also been included.

The projects described below are only those that have had some impact on the contents of this publication. There has been a host of other projects during the last 10 or 15 years in the area of maritime communication.

9.1 DISC

The DISC (Demonstration of Integrated Ship Control) and DISC II project investigated and demonstrated integrated ship control systems (ISC). DISC did this through a set of workshops and a development of general principles for ISC, DISC II through an actual demonstration. DISC had run from late 1996 to mid 1997.

While the focus in DISC was on ship control, it produced a fairly comprehensive reference on principles and standards for ship systems, including communication. Some of this is relevant particularly for safety related issues [DISC]. Many DISC results were afterwards embedded in the PISCES development.

9.2 PISCES

PISCES (Protocols for Integrated Ship Control and Evaluation of Situations) was a research project for the Telematics Application Programme, European Commission‘s Directorate General XIII. PISCES was approved as a research project in the autumn of 1997. The project started in December 1997 and ended in 2000.

PISCES specified, developed and implemented a new protocol standard for Integrated Ship Control (ISC) systems [PISCES]. It is based on the MiTS (Maritime Information Technology Standard) protocol and is closely linked to MiTS Forum [MiTS].

The result of PISCES was mainly [IEC 61162-4], an international standard for ISC protocols. PISCES also developed software, but not to commercial quality. Thus, the implementation of PISCES results is still to a large degree missing.

9.3 COMMAN

COMMAN (Communication Manager System for Data Exchange for Ship Operations) is an EU fourth Framework Programme (DGXIII, Telematics Application Programme, Project No TR4006) that started in September 1998 and was completed in August 2000. The COMMAN Project’s main objective is the production and validation of a ship borne communication manager architecture, followed by a technology demonstrator to show the concept in practice.

It has been established that the maritime user requires an open, Internet based communication network, which needs to allow communication paths to be established between the vessel and a variety of users, such as a shipping company or vessel traffic management system. Such a network incorporates a diverse set of component networks, providing integration of the ship in corporate intranets and connection to wide area networks.

International standards for communications protocol will be used to ensure (global) interoperability and handle the requirements of mobile ship-shore data communication. The COMMAN Single Data Node (SDN) is essentially a network Communication Manager that includes extended routing capabilities. The SDN interfaces, on one side, to the onboard voice and data networks and, on the other, to the external communication bearers, thereby establishing connectivity to end points ashore. The end points may reside on either a corporate intranet, the Internet or on other networks [COMMAN].

9.4 SWAN

SWAN was a thematic network project funded by the IST Programme (Information Society Technologies) of the European Commission. The project started on the 1st of November 2000 with duration of 36 months.

SWAN goal was to support research projects of the IST programme working in the area of waterborne transport by, among other things, to provide information on the standardization process for information and communication systems applied to waterborne transport and help to review the state of the art/practice (systems, services and tools) in important thematic areas of Telematics and Information Technologies [SWANW].

SWAN has among other things also produced a fairly comprehensive report on communication requirements and systems for the maritime industri [SWAN].

9.5 DSS_DC

DSS_DC (Decision support system for ships in degraded condition) is an ongoing EU project. It started mid 2005 and has a duration of 30 months. The main focus is DSS for ships in degraded condition, e.g., hull damage, flooding or propulsion problems, but it also addresses generic emergency management practices, including communication between ship and SAR/shore office.

One report from DSS_DC has been used as background in this study. This report contains an overview of communication mechanisms available for wireless communication between ship and shore [TUB].

9.6 InterShip

InterShip is an Integrated project under the sixth Framework Programme. Its main focus is on shipbuilding, but one part of this is integrated digital networks in ships, both for use in the yard and for the ship itself. No data is yet available on results or conclusions from the project [InterShip].

10 Conclusions

This document has summarised issues that are of interest in the context of broadband communication on ships and between ship and land. As the document is intended as a state of the art study, this section will not try to define any requirements or specify any implementation of a mobile islands network or other forms of information infrastructure standards. However, with the mobile islands network as reference, we will try to sum up some results from this study.

One should also note that the main emphasis in WP2.2 is the communication *mechanisms* that shall facilitate the new functionality that shall be developed in MarNIS. However, the use of new technology must also be based on existing or emerging needs as documented by this report. Thus, in the further work both applications and technology needs to be considered. There will also be differences in need between the different ships:

- *Passenger ships* will probably have passenger demand, revenue generating services and possibly safety as driving forces for even higher bandwidth requirements;
- *Cargo ships* will most likely have efficient operation and legislative requirements as most important driving forces.

In all cases it is mainly economical factors that determine the use of communication. If it is cost effective to send a certain amount of data, it will be done. If not, one will wait. Thus, the cost of the communication services will be vital to how widely they will be used.

One should also note the possibility to change communication system and by that costs dependent on where the ship is. Particularly with the advent of 3G mobile systems and port wireless networks, this facility can be an important factor in future high bandwidth communication.

Finally, broadband is a relative term. For most cargo ships, continuous access to 64 kbps or even less is perceived as broadband. However, for passenger ships, several mbps may be to slow.

10.1 Integrated ship network

It is clear that there is an increasing demand for information on the ships. Already, significant amounts of data are used onboard and even more data can be foreseen used in the future. Also data generated on the ship needs to be transmitted to shore or consumed onboard.

It is beyond the scope of MarNIS to develop a complete concept for an integrated ship network. This is part in the scope of [InterShip] and part in the scope of coming projects. However, one should investigate the use of wireless technology on the ship for implementation of the mobile networks islands. This is in part a matter of addressing requirements from ship crew and passengers and partly to ensure connectivity to port networks and other terrestrial networks.

The main uses for an onboard wireless network can be expected to be:

- *Safety*: Emergency management could make very good use of wireless technology. The main problem is that the networks would have to be safety qualified with the complexity, cost and possible liability for any problems this could imply;
- *Maintenance*: Today's maintenance of large, complex and distributed electro-technical systems is time consuming and crew intensive. The use of wireless technology, if possible coupled with locating services could easily be put to good use;

- *Communication*: General ship board communication is now using DECT in many ships and a wireless digital network could easily replace this;
- *Various administrative systems*: Point of sales terminals, fire patrols and other systems could make use of such a system, even if it was not safety qualified;
- *Passenger and crew telephones*: It could also be used by passengers as an alternative to GSM and with the possibility to hook up PCs to the network.

In theory one could also look at the automatic integration of port networks or other ship networks. However, although this would be interesting for, e.g., SAR operations, it is not clear that this is feasible. The main problem is the need for standardisation and quite accurate adherence to the standard, while interconnection via another mechanism may actually be just as good. Other mechanisms could be a gateway via satellite, GSM or via a one point WLAN connection to the shore network.

10.2 Integrated port network

The selection of technology to implement a port information network will mainly be driven by available technology and commercial needs. This is beyond the ability of MarNIS to influence. However, the issue of ship-port communication and interaction needs to be addressed. In many cases, this will be a sub-set of the normal ship to shore communication, and thus an item under the infrastructure issue. However, for ships approaching ports, there is a possibility to communicate directly with a port based wireless network. Such networks have already been deployed in Amsterdam, Espoo and other Finish ports [RN04] and there are obvious benefits to such systems. MarNIS should investigate how such systems can be used to give ships broadband access and how ship processes can adapt to the different bandwidths that are available. Particular issues that can be investigated are:

- General broadband communication for, e.g., updates of electronic charts, system maintenance etc.;
- Additional port information services, making use of the added bandwidth;
- Emergency management involving ship and port resources.

These issues are not directly in the scope of WP2.2, but their impact on communication bandwidth demand will define overall communication requirements. One should also note that there are benefits also for the port operation in the use of wireless networks. Again, if communication can be combined with location services, new and more efficient resource management can be the result. This applies both to normal operation and to emergency management. Again, this is not directly in the scope of WP2.2.

10.3 SAR and VTS

SAR and VTS are services more or less controlled by international agreements and legislation. Thus, one should be careful in MarNIS to focus too much on technology. There are clear benefits in particularly SAR work in having a broadband communication with the distressed ship, but such communication cannot be relied on unless it is mandatory requirement for a large number of ships. It is highly unlikely that this will happen.

However, for passenger ship having a regular route through a SAR area, it may be possible to use high bandwidth communication in emergency situations. This can be based on IMO requirements for ferry operators to establish formal plans for cooperation with SAR centres in area that the ship regularly travels [MSC864]. However, such services should be set up over a standard Internet link between the SAR centre and the ship and will only be an additional case for the use of this link.

Other than that one can assume that the AIS system and other existing systems such as SafeSeaNet can be used to good effects in these application areas. The need for additional information will again be a question of using available Internet connectivity.

10.4 Terrestrial networks

Terrestrial networks are rapidly evolving and one cannot assume that the maritime sector will be an important factor in the selection of technology, functionality or deployment in this area. This will be treated as a boundary condition in the further work.

10.5 Communication infrastructure

MarNIS will not be able to influence the development of the communication infrastructure for the mobile island network. However, MarNIS can be instrumental in specifying how available technology and systems can be used in the context of the mobile island network. This will then include technical and operational requirements for ship and port systems as discussed above.

Thus, the development of performance specifications and standards should be given a high priority in further work. This must, however, be seen in the context of the ship and port networks and with general terrestrial and wireless systems as well understood boundary conditions.

11 References

[abIDC] WiMax: Optimism ... and Caution, Jeff Goldman, WiFi planet (http://www.wi-fiplanet.com/wimax/article.php/3461391).

[AMVER] AMVER web site at http://www.amver.com.

[ANM23] UK Admiralty Notice to Mariners 23/04, *High Speed Craft.*

[ARGOS] ARGOS – Basic description of the system (www.argosinc.com): See also www.noaasis.noaa.gov/ARGOS/.

[BC11] Broadcom White paper, IEEE 802.11g. The new mainstream wireless LAN standard, Broadcom Corporation, 07/02/03.

[CEM] CruiseEmail web site on http://www.cruiseemail.com/index.htm.

[COMMAN] COMMAN - Communication Manager System for Data Exchange for Ship Operations, Telematics Application Programme, Transport Sector, Project No TR4006, Deliverable D61: Standard Requirements and Recommendations, Version 1.0, June 2000 (from http://www.cordis.lu/telematics/tap_transport/research/projects/comman.html).

[DISC] Research in Waterborne Transport Area, 6.3.3/26 /2nd call): Demonstration of integrated ship control – DISC, Final report, ID Code: D101.00.01.047.003C, 1998.03.24.

[DS2002] *Wireless broadband on ships*, The Digital Ship, December 6, 2002.

[EDGE] EDGE, Introduction of high-speed data, in GSM/GPRS networks. Ericsson White Paper.

[EU2846] Council Regulation (EC) No 2846/98 of 17 December 1998 amending Regulation (EEC) No 2847/93 establishing a control system applicable to the common fisheries policy.

[Equasis] See www.equasis.org.

[FAL31] Report of the thirty-first session of the facilitation committee, *IMO FAL 31/20*, 23 August 2004

[FFA] Application of the FFA member countries' Fishing Vessel Monitoring System to track live reef fish transport vessels. Forum Fisheries Agency, Honiara, Solomon Islands.

[GALILEO] Galileo information can be found at http://europa.eu.int/comm/dgs/energy_transport/galileo/index.htm.

[GS] Globalstar information at http://www.globalstareurope.com.

[HANSA09] HANSA International Maritime Journal, 09/2004.

[ICL03] Institute of Shipping Economy and Logistics (ICL), *Shipping Statistics yearbook 2003*, Bremen, Germany 2003.

[ICO] ICO information can be found at www.ico.com.

[IDC] Worldwide WiMax Semiconductor 2004-2008 Forecast and Analysis: New Markets Show Potential, IDC 2005 (www.idc.com).

[IEC61993] IEC 61993-2 (2001-12-17) Maritime navigation and radiocommunication equipment and systems - Automatic identification systems (AIS) - Part 2: Class A shipborne equipment of the universal automatic identification system (AIS) - Operational and performance requirements, methods of test and required test results.

[IEC62287] IEC 62287 Maritime navigation and radiocommunication equipment and systems - Class B shipborne equipment of the Automatic Identification System (AIS) using CSTDMA techniques – Operational and performance requirements, methods of test and required test results (Committee Draft for Voting, 2005).

[IEC61162-1] *Maritime navigation and radiocommunication equipment and systems - Digital interfaces. Part 1: Single talker and multiple listeners.*

[IEC61162-2] *Maritime navigation and radiocommunication equipment and systems - Digital interfaces. Part 2: Single talker and multiple listeners, high-speed transmission*

[IEC61162-3] *Maritime navigation and radiocommunication equipment and systems - Digital interfaces. Part 3: Small ship network (to be published).*

[IEC61162-4] IEC 61162-4 series of standards: *Maritime navigation and radiocommunication equipment and systems - Digital interfaces. Part 400: Multiple talkers and multiple listeners - Ship systems interconnection.*

[IG04] InfoGenesis case Study: Queen Mary 2 (see www.infogenesis.com).

[InterShip] 6FP IP, http://www.intership-ip.com/.

[IRIDIUM] Iridium Satellite LLC information can be found on http://www.iridium.com.

[LRF] Lloyd's Register Fairplay, Sea-web ship database (www.sea-web.org).

[LRIT] IMO/IALA Seminar on the Automatic Identification System (AIS), London July 2002, *AIS long-range ship reporting*, Wim F.M. van der Heijden (http://www.iala-aism.org/mainsite/pages/english/p4/publicationsE/IMOAIS/4-3.pdf)

[MCP] Maritime Communications Partner AS, Grimstad Norway, http://www.mcpinc.biz/.

[MiTS] Maritime Information Technology Standard [www.mits-forum.org].

[MBTCP] *MODBUS Application Protocol Specification V1.1.*, June 04, 2004. (available from www.modbus.org).

[MSC864] MSC/Circular.864 - Guidelines for Preparing Plans for Co-operation between Search and Rescue Services and Passenger Ships on Fixed Routes.

[NAVTEX] IMO NAVTEX Manual, 2001 Edition.

[NMEA0183] NMEA Interface standard, Version 3.01, January 2002, www.nmea.org.

[NMEA2000] NMEA Interface Standard, Beta version, www.nmea.org.

[OC] Orbcomm information on http://www.orbcomm.com.

[Olex] http://www.olex.no/

[OPCDA] *OPC DA 2.05.1.0.1 specification*, OPC Foundation, 2002-06-28. See additional specifications at http://www.opcfoundation.org/.

[OSV] OSV Code - Code of Safe Practice for the Carriage of Cargoes and Persons by Offshore Supply Vessels. Available from IMO and other sources.

[PISCES] fact sheet, PISCES - Protocols for Integrated Ship Control and Evaluation of Situations, A research project for the Telematics Application Programme, European Commission's Directorate General XIII (www.mits-forum.org).

[PRWP] The broadband wireless access market, Evolution of the WiMax standard. Proxim White Paper PP2-0604, Proxim Corporation 2004.

[RN04] Port of Amsterdam goes WiFi, http://www.radionet.com/Default.aspx?id=318051, June 2004.

[SARSAT] INTRODUCTION TO THE COSPAS-SARSAT SYSTEM, C/S G.003, Issue 5 - Revision 1 (available from http://www.cospas-sarsat.org/DocumentsGSeries/g3oct29.pdf). October 1999

[SATPOINT] SatPoint AB, Lindingö, Sweden. http://www.satpoint.se/

[SafetyNET] *SafetyNET User's Handbook*, 3rd Edition (PDF), June 2000, Maritime Safety Services Department - Inmarsat Ltd (http://safety.inmarsat.com/snet.pdf).

[SaSN04] *Safety at Sea International*, USCG tracking plan is "data for data's sake", November 2004.

[SFV] Consolidated text of the regulations annexed to the Torremolinos International Convention for the Safety of Fishing Vessels, 1977, as modified by the Torremolinos Protocol of 1993 relating thereto (SFV 77/93). Available from IMO and other sources.

[SIRENAC] http://www.emsa.eu.int/end185d002.html and www.parismou.org.

[SMS] *What is SMS?* Simon Buckingham, GSM Association Website (http://www.gsmworld.com/technology/sms/intro.shtml).

[SOLAS] SOLAS, *Convention for the Safety of Life at Sea*, International Maritime Organization.

[SSAS] IMO MSC Resolution MSC.136(76) - Performance Standards for a Ship Security Alert System, (adopted on 11 December 2002).

[SSN] DIRECTIVE 2002/59/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 June 2002 establishing a Community vessel traffic monitoring and information system and repealing Council Directive 93/75/EEC.

[SWAN] State of the Art - Current state in maritime, mobile & satellite communications, SWAN Deliverable D2.1, 2001-11-30.

[SWANW] See http://www.ist-swan.net/.

[TESTA] Public investment in information technology generates real cost savings, says Commission study, EU Press release, Reference: IP/03/1358 Date: 09/10/2003.

[TNMR] Telenor Maritime Radio, Description of sea mail as services (in Norwegian - see http://www.maritimradio.no/).

[TUB91] State of the Art in Wireless Communication, deliverable 9.1 in DSS_DC project, C.-U. Böttner, Technical University of Berlin, TUBMAT10R01.

[UMBS] Application note: UMTS Base Station Feeding Using Alvarion's WALKair 3000, Alvarion at www.alvarion.com.

[WiMax] SDR ARCHITECTURE IDEALLY SUITED FOR EVOLVING 802.16 WIMAX STANDARDS Michael Komara, Chief Scientist; AirNet Communications Corp., Melbourne, FL, USA, October 2004.

[ZB] ZigBee (Almost) Arrives, Eric Griffith, WiFi Planet (http://www.wi-fiplanet.com/news/article.php/3448861).

[WB11A] Toshiba IK-WB11A Wireless Indoor/Outdoor Network Camera product data sheet.