D2.7 Concept and specification for seamless roaming

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1 Scope of the document

The following document is a deliverable D2.7 of the EfficienSea 2 project. It describes the concept of the seamless roaming for the purpose of the hybrid communication system. Seamless roaming is a mechanism which selects the most suitable (given the radio channel quality or service requirements) communication link. To do so, two major components of the seamless roaming have to cooperate: a radio monitoring entity and radio link selection block. In the document, the details regarding those two components and the relevant algorithms will be provided. The document will also discuss the initial concept of the Maritime Cloud cooperation with the hybrid communication system using the Seamless roaming mechanisms. (This concept will be further developed in 2016, during our work towards deliverable D2.8.) Additionally, a description of the hybrid communication system architecture will be provided, as well as the concept of the hardware implementation (laboratory prototype) of the system's on-board module.

Based on a study of existing and new solutions and requirements, strategies will be developed for hybrid solutions for channel selection based on availability, cost, restrictions in bandwidth and other technical parameters, but also content priority.

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2 Abbreviations

AIS	*Automatic Identification System*
EDGE	*Enhanced Data Rates for GSM Evolution*
FTP	*File Transfer Protocol*
GPS	*Global Positioning System*
HSPA	*High Speed Packet Access*
HTTP	*Hypertext Transfer Protocol*
LTE	*Long Term Evolution*
MCC	*Maritime Cloud Client*
MIMO	*Multiple Input Multiple Output*
MMS	*Maritime Messaging Service*
NAVTEX	*Navigational Text Messages*
OSI	*Open System Interconnection*
REST	*Representational State transfer*
SOAP	*Simple Object Access Protocol*
TCP/IP	*Transmission Conrol Protocol/Internet Protocol*
UDP	*User Datagram Protocol*
VDE	*VHF Data Exchange*
VHF	*Very High Frequency*
VSAT	*Very Small Aperture Terminal*
WCDMA	*Wideband Code Division Multiple Access*
WWW	*World Wide Web*

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3 Executive summary

The document, which constitutes a deliverable D2.7 of the EfficienSea 2 project is mainly concentrated on the details of the seamless roaming concept that is foreseen to be employed in the hybrid communication system used at sea and providing services via Maritime Cloud.

This deliverable is composed of three major sections. In the first one, information on the proposed hybrid communication system is provided. The main concept of this system is based on the assumption that connections are set up automatically using different radio interfaces, and the current, most suitable interface is selected from those available by sophisticated algorithms taking into account a number of parameters, including user's preferences. This short definition determines the architecture of such system: it includes the coastal segment which covers the infrastructure of the radio networks, whose technical parameters and base stations' locations enable the communication between users at sea (2G/3G/LTE, VDE-Terrestrial, WiFi, WiMAX, etc.), the satellite segment (e.g. VSAT) and the on-board segment which includes systems and interfaces installed on board of the ship.

In the same section, a concept of the hardware implementation of the hybrid communication system's on-board module is discussed. This module will be necessary in the upcoming tests of the resulting system (and the particularly the seamless roaming efficiency), but it has to be underlined the presented concept is not a concept of a target device to be installed on-board of actual vessels, but rather a laboratory prototype which offers a full functionality but its sole purpose is the testing process. In the document, all the components have been described, including the control unit (a "heart" of the module), GPS receiver, AIS receiver, GPS/3G/LTE modem, WiFi modem and necessary antennas.

The next section of this deliverable is concentrated on the concept of maritime cloud to be employed in the system. First, some basic theoretical information about the concept of Maritime Cloud has been provided, including the Maritime Service Portfolio Registry, Maritime Identity Registry and the Maritime Messaging Service MMS (i.e. a primary Maritime Cloud service). Then, some information about the maritime cloud client has been included (the client is an entity via which the maritime Cloud services are provided to ship/coastal applications). First, the authors discussed a well-known OSI layer model of the client and presented the functions of each of the layer. One of the goals of the project is finding a way the Maritime Cloud and the hybrid communication system could cooperate with one another. To do so, a concept of the interface between these two elements was proposed. The authors developed a modified architecture of the Maritime Cloud Client (MCC) which includes components of both the hybrid system and the Seamless Roaming. In this novel concept, the higher layers of the Maritime Cloud Client component operate exactly as in the legacy architecture, but several new elements have been added, most notable a "roaming device" comprised of the network monitoring entity and radio link selection block. In the proposed architecture, the radio link selection block can choose from systems belonging to two separate categories: IP-based

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systems and non-IP based systems. Additionally, the proposed concept assumes than an IP-based signaling channel between Maritime Cloud layer and the roaming device will be utilized. This channel is necessary mainly because the MCC is almost at the top of the layer model and the roaming device requires a lot of data from higher layers (e.g. service type, user preferences, GPS/AIS data, etc.).

In the same section, a notion of endpoints has been presented. Basically each service can have any number of endpoints. Some examples of the endpoints are: http, https, ftp, mailto, mms, tcp, udp, tel, vhf, ais, navtex, navdat, dgnss. Every service registered in the Maritime Cloud has a set of endpoints, through which this service can be utilized. Likewise, the onboard module of the hybrid communication system will be equipped with its own endpoints (defined specifically for the system), and it will utilize Maritime Cloud services using those endpoints. Consequently, the deliverable states that endpoints are basically an interface between the hybrid communication system and the Maritime Cloud.

The last section discusses in detail the concept of the seamless roaming. First, it provides a thorough analysis of the seamless roaming algorithm and after that, it introduces two major components, i.e. the network monitoring entity and radio link selection block. The first one is responsible for the periodic quality tests of the available communication systems. The monitoring of the radio links is conducted both during data transmission (i.e. when a service is being carried out) and when the system is in stand-by mode (waiting for another task). The frequency of those tests will depend on the radio system type, utilized equipment, etc. The radio links testing is based mainly on the measurement of the radio signal level and on the analysis of the broadcasted network quality parameters (without setting up the actual connection with the network). The result of this procedure is an input to the second discussed component – a radio link selection block. This block it is responsible for selecting the optimal method of transmission in the given time and place on the basis of the information provided by the network monitoring entity and then – if required – is also responsible for switching between various data transmission technologies. The procedure of radio link selection and (perhaps) switching is carried out periodically during the connection (not just once when the connection is set up), because the availability and quality of radio networks will vary both in time and space. Generally, from the Maritime Cloud point of view, the radio link selection mechanism will decide which endpoint will be used for the connection.

In the presented concept, the radio link selection will utilize the so-called weighting algorithm. The main assumption of this algorithm is that both the user and the services have priorities and preferences that should be processed by the algorithm. Obviously, not all of those priorities and preferences have to be equally important. Consequently, for a certain service, a set of the most important parameters (from among the radio link selection criteria) will be defined, and then each of those parameters will be assigned a weight coefficient. Additionally, to give the user more freedom, it will be possible to modify (within reasonable limits) some of those parameters.

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The deliverable is concluded with a practical example of the Seamless roaming utilization in a real scenario.

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4 Specification of the hybrid communication system

The hybrid communication system – developed in the EfficienSea 2 project – is to provide access to several services offered via Maritime Cloud. The main concept of the system is based on the assumption that connections are set up automatically using different radio interfaces, and the current interface is selected from those available by sophisticated algorithms taking into account a number of parameters, including user's preferences. The following chapter describes the system architecture, as well as its components and the relevant communication protocols. Additionally, the proposed concept of the Maritime Cloud interface will be discussed. The selection of the most suitable radio link will be performed through Seamless Roaming mechanisms which will be introduced in the chapter "Seamless Roaming concept".

4.1 System architecture

The architecture of the hybrid communication system is illustrated in fig. 1.

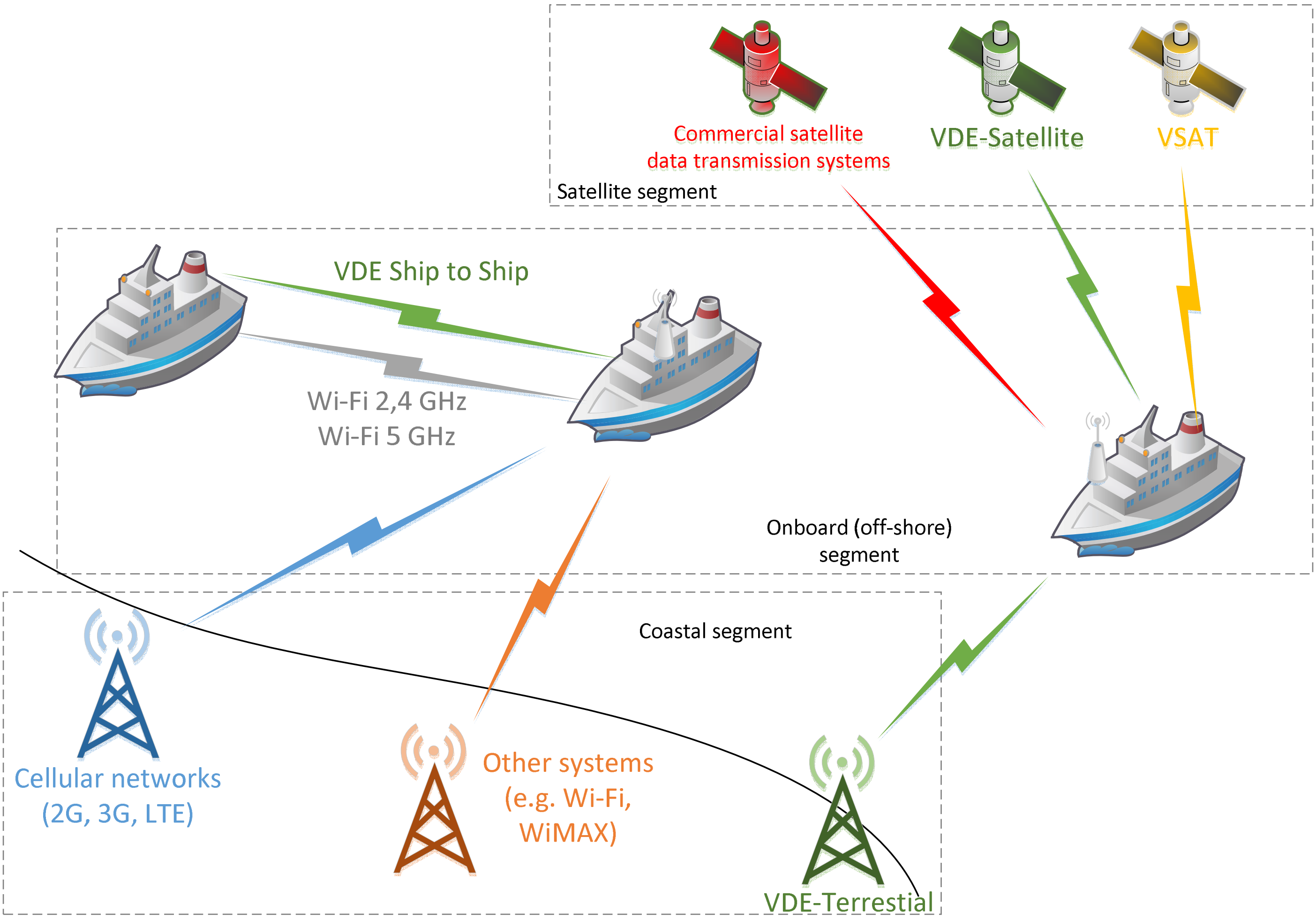

Fig. 1. The architecture of the hybrid communication system.

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The hybrid communication system is comprised of three main segments:

- The coastal segment,
- The onboard segment,
- The satellite segment.

The coastal segment covers the infrastructure of the radio networks, whose technical parameters and base stations' locations enable the communication between users at sea. In particular, this segment comprises:

- Cellular networks (2G, 3G, LTE),
- VDE-Terrestial (work underway),
- Other (might potentially become part of the coastal segment):
    - WiMAX networks,
    - Wi-Fi networks (only in the vicinity of ports – due to limited operating ranges of these networks).

Satellite segment covers satellite systems that successfully provide communication links on areas where terrestrial systems are unable to do so. In particular, this segment comprises:

- VDE-Satellite (work underway),
- VSAT,
- Other commercial satellite data transmission systems.

It goes without saying, it is way beyond the scope of the EfficienSea 2 project to modify or alter the infrastructure of the coastal and satellite segments, so in the following section, we will mainly concentrate on the description of the onboard segment.

The onboard segment includes systems and interfaces installed on board of the ship. Those systems and interfaces enable communication via coastal/satellite infrastructure and also direct ship-to-ship communication (under the condition all involved ships are equipped in compatible interfaces and are sufficiently close to one another). It is assumed direct communication can be carried out via a VDE Ship-to-Ship link or using WiFi networks at 2,45 GHz or 5 GHz. The data obtained from the AIS system (position and bearing of the neighboring ships) allows to identify those ships with which a direct ship-to-ship communication is possible. Additionally, the AIS data helps to calculate distances to the neighboring ships which is one of the factors that determines which technology might be used

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for this ship-to-ship communication. It should also be added that e.g. Iridium system or the MF/HF data services can be used for direct communications as well.

In the next subchapter, the major components and interfaces of the off-shore segment will be presented.

4.2 Components and interfaces description

The general architecture of the onboard (ship) module of the hybrid communication system is depicted in fig. 2.

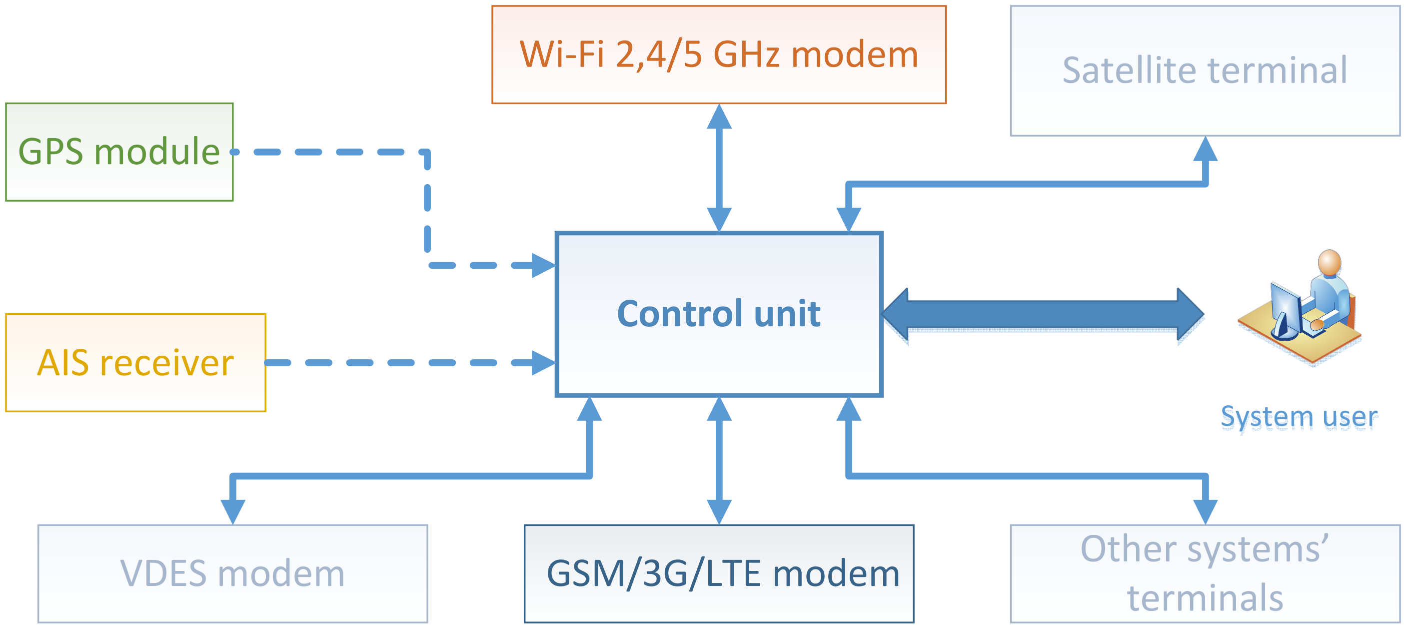

Fig. 2. General architecture of the onboard module.

The central component of the onboard module is the Control unit. It is responsible for several functions, i.e.:

a) configuration of the module's segments and verification if they operate correctly,
b) monitoring of the radio links and switching between them,
c) setting up the connection link via one of the available radio interfaces.

In the EfficienSea 2 project, a prototype of the onboard module will be developed. It will comprise devices that support the following technologies: GSM/3G/LTE, Wi-Fi 2.4 / 5 GHz, AIS and GPS. Possible integration of the VDES module depends on the date when VDES-devices (commercial ones or prototypes) come into market. A support for other systems such as VSAT or WiMAX is also anticipated.

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4.3 A sample implementation

The following subchapter describes the onboard module's hardware platform for the proposed implementation of the hybrid communication system prototype. Fig. 3 represents a detailed scheme of the module and indicates the selected hardware and interfaces, whereas the algorithm of its operation will be discussed in the next sections of this document.

It should be noted the concept presented below is not a concept of an actual, commercial device ready to be installed on-board and used in operational conditions, but merely a laboratory prototype which offers a full functionality, but is designed strictly for the purpose of the upcoming tests. This approach is in compliance with the expected Technology Readiness Level set for this part of the project at TRL=4-5. Those tests will mainly verify the efficiency and reliability of the seamless roaming mechanisms in various scenarios (e.g. the ability to switch between available communication links depending on the ship's position and user requirements)[1]. One of the scenarios to be performed during the tests will cover a situation where all available radio links are of very poor quality and it is difficult to establish any connection. By doing so we will be able to evaluate the onboard module performance in the worst case scenario.

Additionally, as the implementation will be used mainly by the engineers (during the tests) rather than target users, there is no need to define at this stage any human interface (however, it will have to be proposed during the development of the commercial version of the device).

[1] Also see section „Weighting algorithm of the radio link selection – general concept" in this document.

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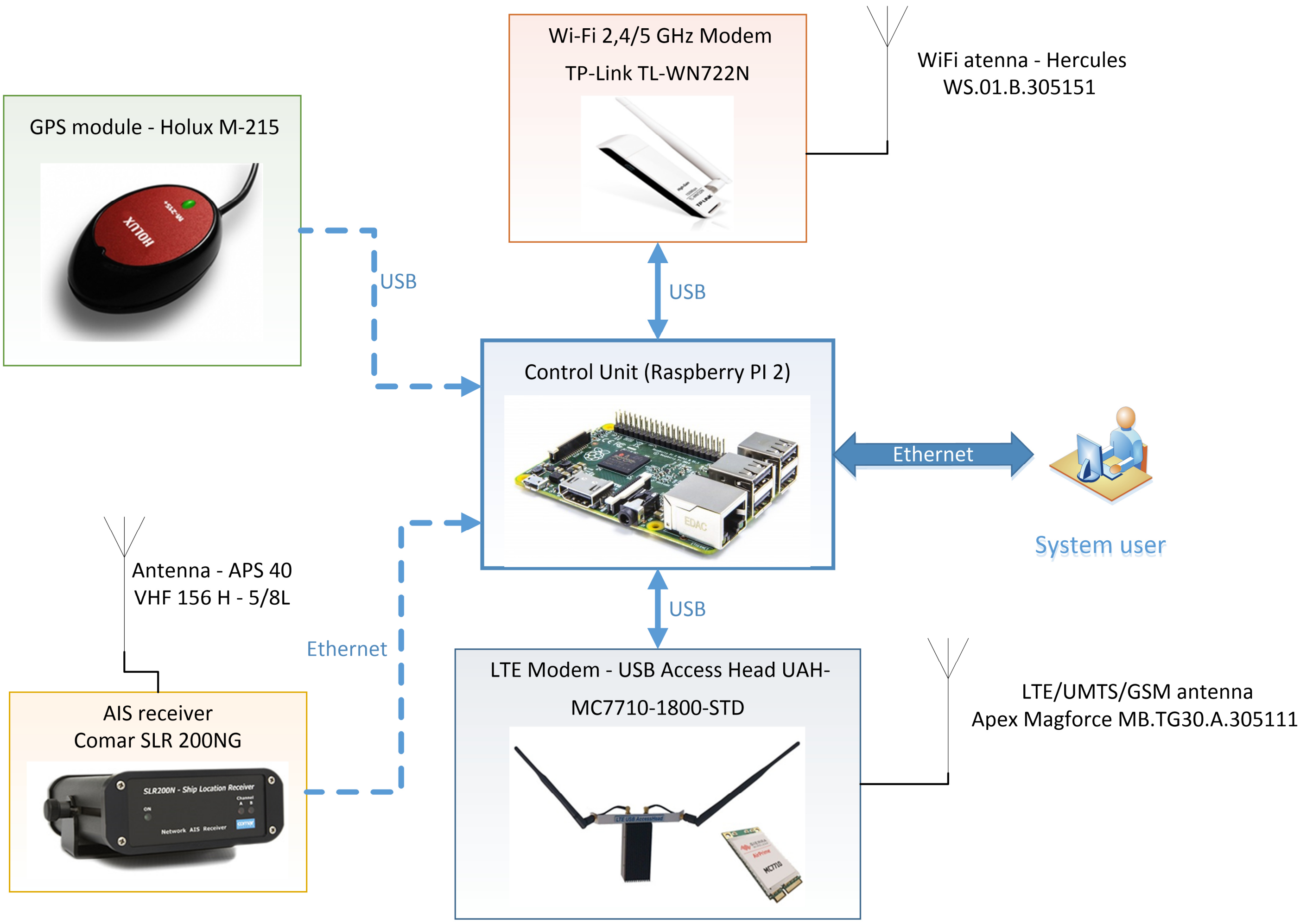

Fig. 3 Proposed hardware architecture of the onboard module

Control unit

All the functions of the control unit are performed by the Raspberry Pi 2 platform. It is a single-board computer, whose major advantages are its versatility (due to a big number of input/output interfaces) and compact size. What is also very important, there is a lot of documentation and software available for this platform. The Raspberry Pi 2 module is depicted in fig. 4.

The major hardware parameters of the Raspberry Pi 2 are as follows [1]:

- Processor: ARM Cortex-A7 900MHz quad-core,
- RAM memory: 1 GB,
- File system: microSD card (up to 32 GB),
- Graphics processing unit (GPU): Broadcom VideoCore IV,
- 4 USB ports,

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- 1 Ethernet port,
- 1 HDMI port,
- Power source: 5V (via micro USB),
- 40 I/O pins.

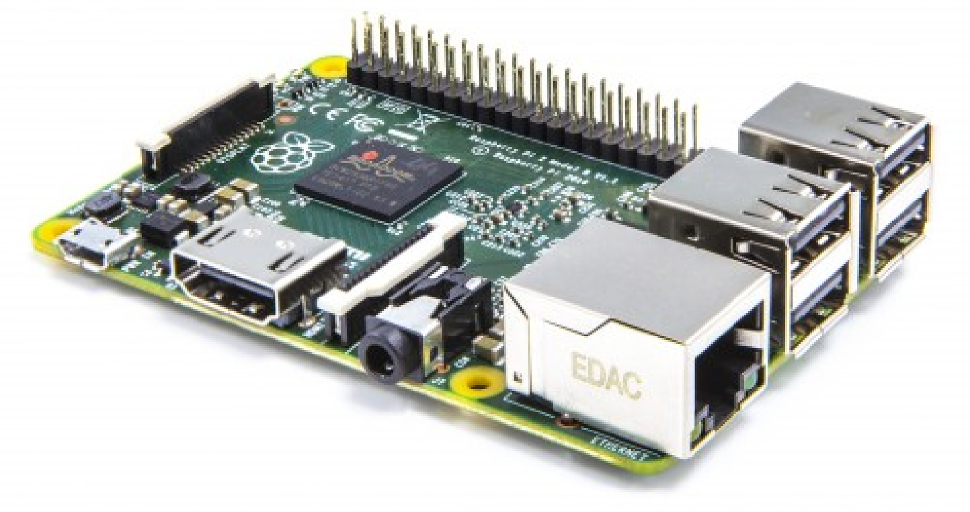

Fig. 4. Raspberry PI 2 platform.

GPS module

GPS Holux M-215+ module is a wired GPS receiver equipped with a MTK MT3333 chipset that supports GPS and GLONASS systems. It is connected to a computer via USB, RS-232 or RJ-45. The module provides high accuracy of localization, low power consumption and it is water-resistant (IPX-7 standard). On its cover, there is a LED diode indicating current status of the device. The sensitivity of the Holux M-215+ is –159 dBm and the cold-start time is below 31 s. The devices is presented in fig. 5.

It should be observed that the target, commercial on-board device (as opposed to the one presented here) would not need an external GPS receiver, because GPS is a part of a typical on-board equipment.

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Fig. 5. GPS Holux M-215 module.

AIS receiver

The function of the AIS receiver will be performed by the Comar SL 200NG device manufactured by Comar Systems (see fig. 6). It is capable of receiving AIS messages transmitted by both class A transponders installed on vessels above 300 tons and the optional class B transponders.

The major hardware parameters of the Comar SLR 200NG receiver are as follows [3]:

- Sensitivity: –112 dBm,
- Frequency: 161.975 MHz and 162.025 MHz,
- Interface: Ethernet,
- Power supply: 9 – 30 VDC,
- Antenna connector: BNC,
- Data format: ITU/ NMEA 0183.

Fig. 6. AIS receiver (Comar SLR 200NG).

The AIS receiver will operate with an APS 40 – VHF 156 H – 5/8L antenna manufactured by Mitcom Electronic. The operational band of this antenna is in the range of 155-165 MHz, its maximum gain is 5.5 dBi (according to the antenna's documentation) and the maximum transmission power is 300 W. The APS 40 – VHF 156 H – 5/8L antenna is depicted in fig. 7.

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Fig. 7. APS 40 - VHF 156 H - 5/8L antenna.

GSM/3G/LTE modem

The LTE USB Access Head UAH-MC7710-1800-STD [4] will serve as a GSM/3G/LTE module. The device is equipped with the AirPrime MC7710 LTE-HSPA+ card manufactured by Sierra Wireless. This card is effectively a wireless modem supporting the following interfaces:

- GSM,
- GPRS,
- EDGE,
- HSPA+ (Category 24 HSDPA and Category 6 HSUPA),
- LTE (Category 3),

and the following bands:

- LTE 800/900/1800/2100/2600 MHz,
- WCDMA 900/2100 MHz,
- EDGE/GPRS/GSM 900/1800/1900 MHz.

The maximum data rate offered by the modem is 100 Mb/s (downlink) and 50 Mb/s (uplink). Additionally, the card supports a number of techniques utilized in contemporary radiocommunication systems, such as the dual-cell, antenna diversity or MIMO technique (multiple-input multiple-output). The configuration of the device is handled through the AT commands (both standard ones and device-specific – defined by the Sierra Wireless), which significantly simplifies all the procedures performed by the module.

The discussed module is presented in fig. 8.

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Fig. 8. LTE USB Access Head UAH-MC7710 module and AirPrime MC7710 LTE/HSPA+ card.

The LTE/UMTS/GSM modem described above will operate with two Apex Magforce MB.TG30.A.305111 external omnidirectional antennas [5]. This antenna supports three frequency bands: 698 – 960 MHz, 1575.42 MHz and 1710 – 2700 MHz, so it covers almost the entire frequency spectrum utilized by the 2G, 3G and 4G cellular systems. The maximum antenna gain depends on the band and is in the range of 0.62 to 2.97 dBi.

The antenna is placed in a special magnetic mount, so it is very easy to install it on any metallic surface. It is also equipped with a 3-meter long cable type CFD-200 (male SMA connector).

Apex Magforce MB.TG30.A.305111 antenna is depicted in fig. 9.

Fig. 9. Apex Magforce MB.TG30.A.305111 antenna for LTE/UMTS/GSM.

Wi-Fi modem

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The TP-Link TL-WN722N [6] device is a wireless, long-range USB network card, supporting data rates up to 150 Mb/s. It operates in 2.45 GHz band and is compatible with IEEE 802.11b, g and n standards. The card is presented in fig. 10.

Fig. 10. Wireless card TP-Link TL-WN722N.

One of the components of the Wi-Fi modem introduced above is also an external Wi-Fi antenna with a 4 dBi gain, however in the hybrid communication system that antenna will be replaced by an external one: the Hercules WS.01.B.30515. This omnidirectional antenna supports both major Wi-Fi bands, i.e. 2.45 GHz and 5 GHz. The detailed listing of the Hercules antenna technical parameters can be found in document [5].

The Hercules WS.01.B.30515 is depicted below in fig. 11.

Fig. 11. Hercules WS.01.B.305151 Wi-Fi antenna.

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5 The general concept of the Maritime Cloud

The following section discusses the concept of the Maritime Cloud and particularly the way of its cooperation with the hybrid communication system. A modified Maritime Cloud Client architecture will be introduced which includes the so-called roaming device comprised of the network monitoring entity and radio link selection block. Additionally, an interface between the Maritime Cloud and the hybrid communication system will be defined. Both these elements are of paramount importance given the purposes and targets of the EfficienSea 2 project.

Maritime cloud has been defined as a communication framework which enables efficient, secure, robust and trouble-free exchange of information between each and every authorized maritime entity, using available communication systems. The concept of the Maritime Cloud has emerged as a response for the need to create a common framework to facilitate e-navigation services management and to ensure their security.

Fig. 12 depicts a general concept of the Maritime Cloud.

The core of the Maritime Cloud framework is comprised of three key elements, i.e.:

- Maritime Service Portfolio Registry,
- Maritime Identity Registry,
- Maritime Messaging Service.

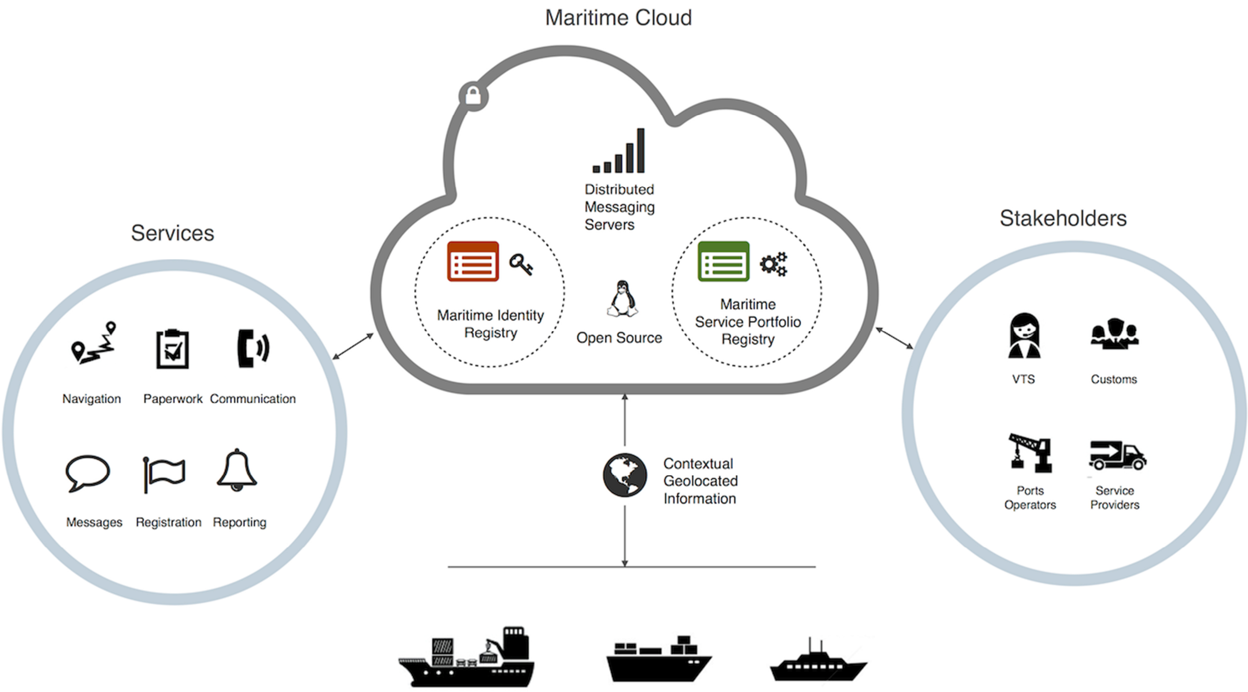

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Fig. 12. Maritime Cloud general architecture [8].

The Maritime Service Portfolio Registry contains a formal description (specification) of the services. The registry is to improve visibility and availability of maritime information and services.

The ships' identification systems (such as ship's name, IMO number, MMSI number) utilized currently do not consider the need of interaction with actors that are not ships and do not have their own radio station, e.g. shipowners or service providers. The Maritime Cloud will provide a maritime identifier (Maritime Identity) in the Maritime Identity Registry, to give access to:

- Certificates for a secure exchange of information with other maritime entities using every channel of communication,
- The Maritime Service Portfolio Registry,
- The Almanac,
- The Maritime Messaging Service.

The Maritime Service Portfolio Registry and Maritime Identity Registry are updated in real time in the central database and those updates are transmitted to the actors.

Every actor has a local copy of the public areas of both the Maritime Identity Registry and the Maritime Service Portfolio Registry; that local copy is referred to as the Almanac. The Almanac will act as a "directory" that includes every registered actor and maritime service, and consequently it will enable an offline[2] access to the framework services and secure communication. Additionally, using the Almanac, the actors (especially the mobile ones) will be able to reduce the frequency of online searching for the contact information – it will be done only to update the required data on-demand and/or only in designated time slots.

Maritime Messaging Service (MMS) is a primary Maritime Cloud service. Its goal is to ensure a seamless information exchange between different communication links. MMS is based on Internet connection, but on the other hand, every alternative communication interface may be switched on and utilized by the MMS via dedicated network gateways. Thanks to this approach, for example a message sent by "ship A" connected to the MMS via Inmarsat can be received on "ship B" through an Iridium terminal and through HF link on "ship C" or it can be received by a VTS operator with a DSL-based Internet access.

Consequently, it can be stated the MMS is a mechanism that offers communication between the actors that are unable to communicate directly, i.e. do not have compatible links, or they do but those links are temporarily unavailable. In such a case, the communication is performed via a central server. In case one of the actors is unable to connect, the MMS can keep their

[2] i.e. the actors do not need to be connected to any communication link to exploit the Almanac.

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message in a queue for a specified amount of time. In fig. 13, the communication in Maritime Cloud using the MMS is schematically presented.

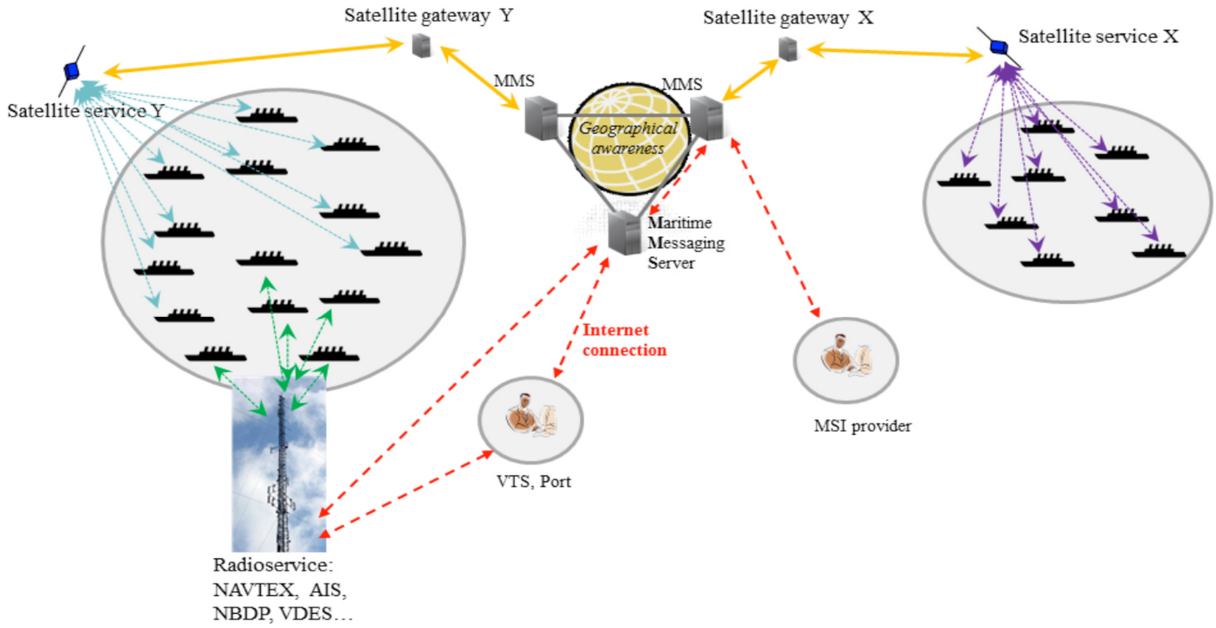

Fig. 13. General concept of the MMS service in the Maritime Cloud [8].

Additionally, the MMS service supports geocasting.

Geo-messaging is a messaging protocol that works on top of the TCP/IP protocol. It allows to send messages to actors (within a certain geographic area – geocasting) based on their maritime identifier. The actors need to monitor (listen) a specified area defined (and limited) by the technical capabilities of the communication system. The concept of geocasting is presented in fig. 14.

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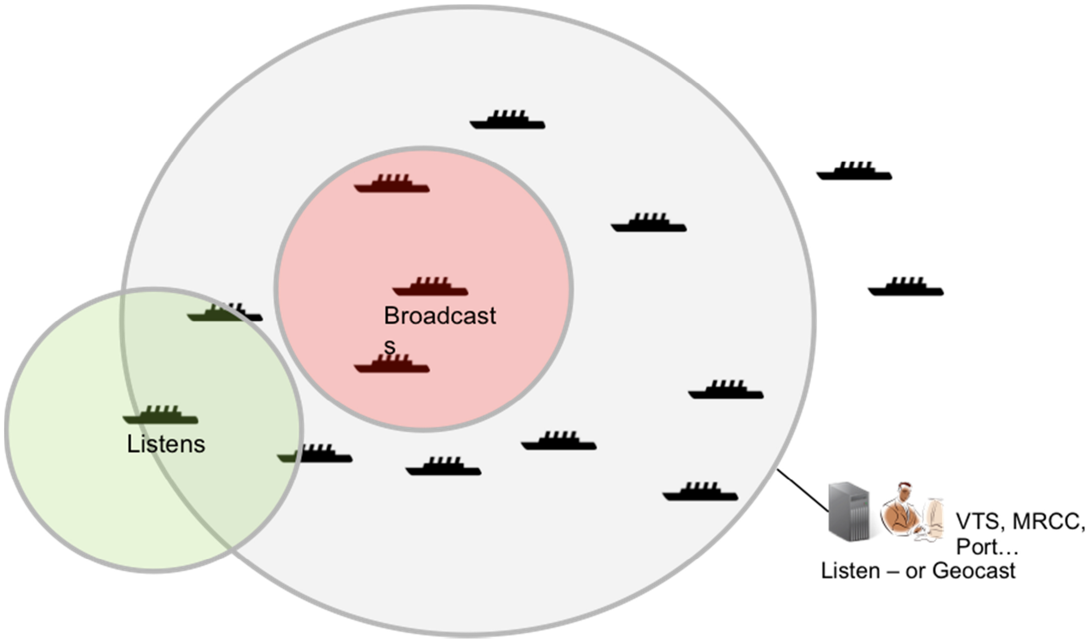

Fig. 14. General concept of geocasting [8].

5.1 The Maritime Cloud client

The Maritime Cloud services will be provided to ship/coastal applications via the so-called Maritime Cloud client. This component will enable a proper operation of the Maritime Cloud services – independently of hardware elements – by providing roaming between various data transmission systems. Obviously the types and number of utilized systems will be different for different actors; some of them will be using many various systems, whereas others – only the mandatory ones. The client component will act as a local concentrator of information, and will be equipped with a link to appropriate sensors, navigation data and telecommunication devices.

The API interface of the Maritime Cloud client will provide services for:

- Security – by utilizing the Maritime Identity Registry (online) or by utilizing the information included in the Almanac (offline),
- Detection of services – by utilizing the Maritime Identity Registry (online) or by utilizing the information included in the Almanac (offline),
- Dynamic services, e.g. a ship providing its own navigation and location data,
- Communication utilizing seamless roaming to replace the primary communication link by a more suitable one (given the specific purpose and the user's requirements at the moment).

The component will provide access to the Almanac and will support update procedures.

Fig. 15 depicts the architecture of the Maritime Cloud client shown as a layer of the OSI model.

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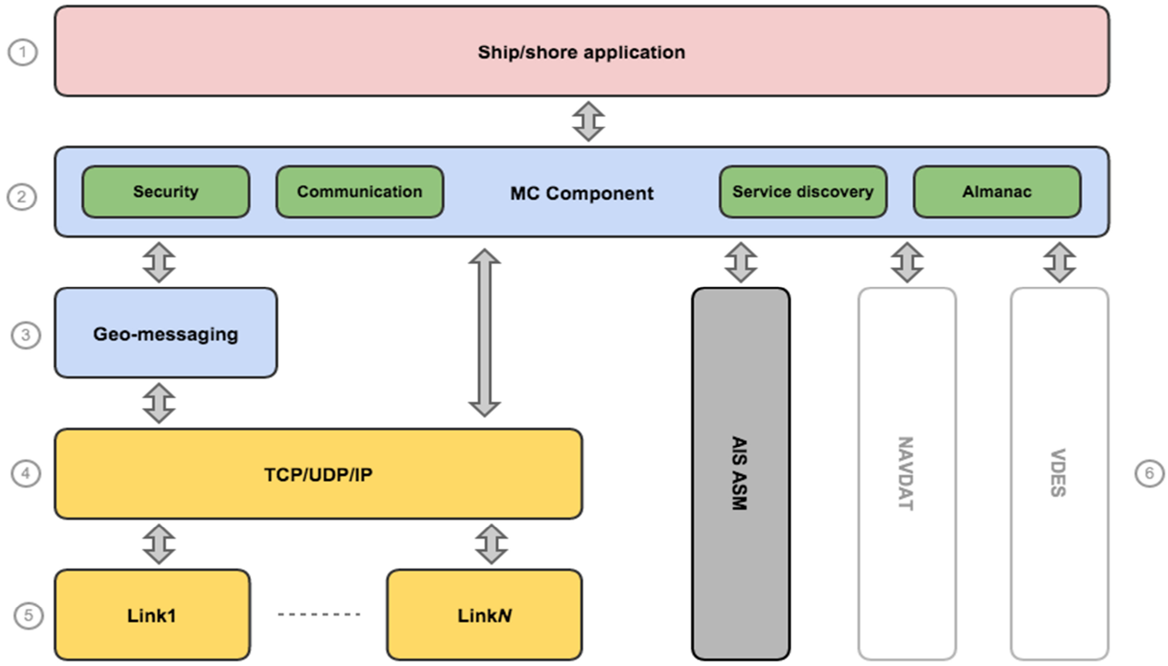

Fig. 15. The Maritime Cloud client component shown as a layer of the OSI model [8]

The numbers 1-6 denote respectively [8]:

1. Application layer - The application layer consists of:
    a) Ship and shore side applications offering functionality to users.
    b) Applications providing maritime services.
    c) Components offering services to applications.
2. Maritime Cloud layer - Encapsulating complexities of communication and offering an interface to Cloud functionality.
3. Geo-messaging protocol - A geo-aware messaging protocol on top of Internet transport protocols.
4. TCP/UDP/IP - Internet protocol (IP) and transport protocols TCP and UDP. Through the use of Multi-WAN routers the layer will be able to select among a number of physical links.
5. Link layer - A number of link layer protocols using physical means. E.g. mobile broadband, SAT, WiMAX.
6. Non-Internet communication systems - A number of communication systems each consisting of different layers. Each communication system will have a set of properties. E.g. bandwidth, range and abilities of the communication system.

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5.2 The proposed concept of the Maritime Cloud interface

Using the information provided in the previous section, the concept of the connection (interface) between the hybrid communication system and the Maritime Cloud has been developed. Fig. 16 presents the modified version of the Maritime Cloud client. This figure indicates how elements of the new hybrid communication system could be incorporated into the existing concept of the Maritime Cloud client architecture.

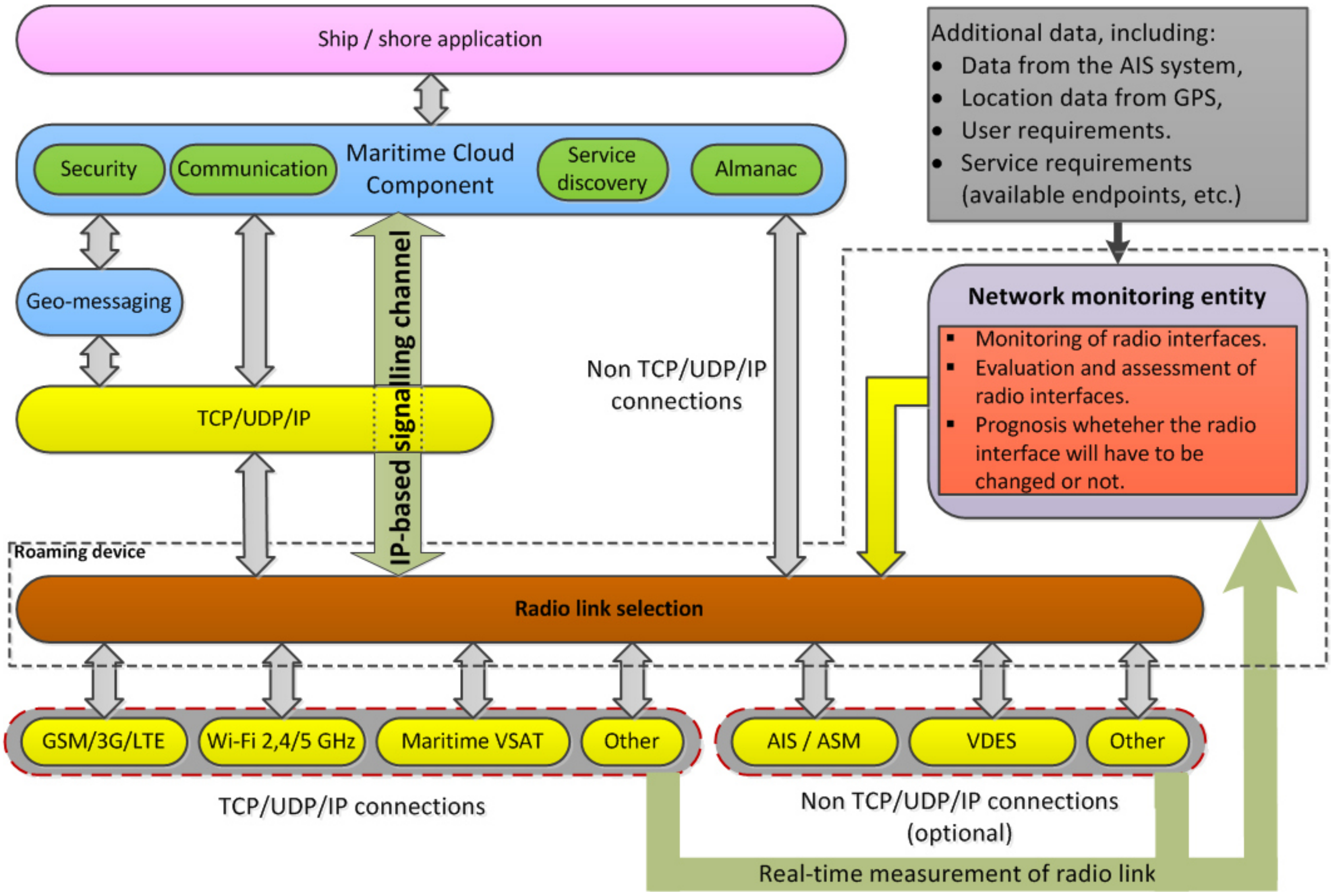

Fig. 16. The architecture of the Maritime Cloud client connected with the components of the hybrid communication system and the Seamless Roaming

In the proposed modification of the architecture, the higher layers of the Maritime Cloud client component operate exactly as it has been described in the previous subsection (no changes are proposed). The blocks of the radio link selection and network monitoring are the "core" of the Seamless Roaming concept, and their detailed description will be provided in the next chapter. These two elements constitute the so-called "roaming device". As we can see, fig. 16 clearly distinguishes a separate category of non-internet communication systems (i.e. systems

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which are not based on IP protocol), e.g. AIS or VDES. Potentially, both group of systems (i.e. TCP/UDP/IP systems and Non TCP/UDP/IP systems) may also contain novel and anticipated solutions, e.g. those developed currently in other research projects (such as the NetBaltic project in Poland [9]). Each of those systems may have different architectures and different sets of parameters, including transmission bandwidth, range or achievable throughputs.

From the Maritime Cloud interface's point of view, it is significant that every service registered in the Cloud is always a service of a certain type. Currently, the following types of Maritime Clouds services have been identified:

- M2M (Machine-to-Machine) services: MMS, HTTP, REST, SOAP, TCP, UDP, ISASM;
- NonM2M (Non Machine-to-Machine) services: FTP, WWW, VHF, TEL, NAVTEX, DGNSS, EMAIL.

The projected hybrid communication system assumes the so-called endpoints will be utilized as the interface to the Maritime Cloud. Each service can have any number of endpoints. So far, the following types of endpoints have been defined: http, https, ftp, mailto, mms, tcp, udp, tel, vhf, ais, navtex, navdat, dgnss. Every service registered in the Maritime Cloud has a set of endpoints, through which this service can be utilized. Likewise, the onboard module of the hybrid communication system will be equipped with its own endpoints (defined specifically for the system), and it will utilize Maritime Cloud services using those endpoints. <u>Consequently, it can be stated that endpoints are basically an interface between the hybrid communication system and the Maritime Cloud</u>. This concept will be further developed

Additionally, the proposed concept assumes than an IP-based signaling channel between Maritime Cloud layer and the device responsible for roaming will be utilized (as it is indicated in fig. 16). This channel is necessary mainly because the MCC is almost at the top of the layer model (below the application layer, to be precise) and the roaming device requires a lot of data from higher layers, such as:

- The type of the service/endpoint the user will use – this information will ultimately translate into the actual selection of the radio link;
- High level user preferences – which are essential for the roaming algorithm;
- High level AIS and GPS data – to be used by both the roaming device and roaming algorithm.

The proposed signaling channel, which will be based on TCP/UDP protocols, will be capable of sending the above data and, if necessary, commands between the MCC and roaming device. From the technical point of view, a specific port number might be utilized for the latter purpose.

An important feature of the proposed solution is that it is transparent to the onboard network that is being developed in Task 2.4 of the EfficienSea 2 project.

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The detailed specification of the Maritime Cloud interface will be provided in the deliverable D.2.8 which will be released in the 18th month of the EfficienSea 2 project.

5.3 Example of a service in Maritime Cloud

An example of the registration in the Maritime Cloud and the lifecycle of the Maritime FTP service is depicted in fig. 17.

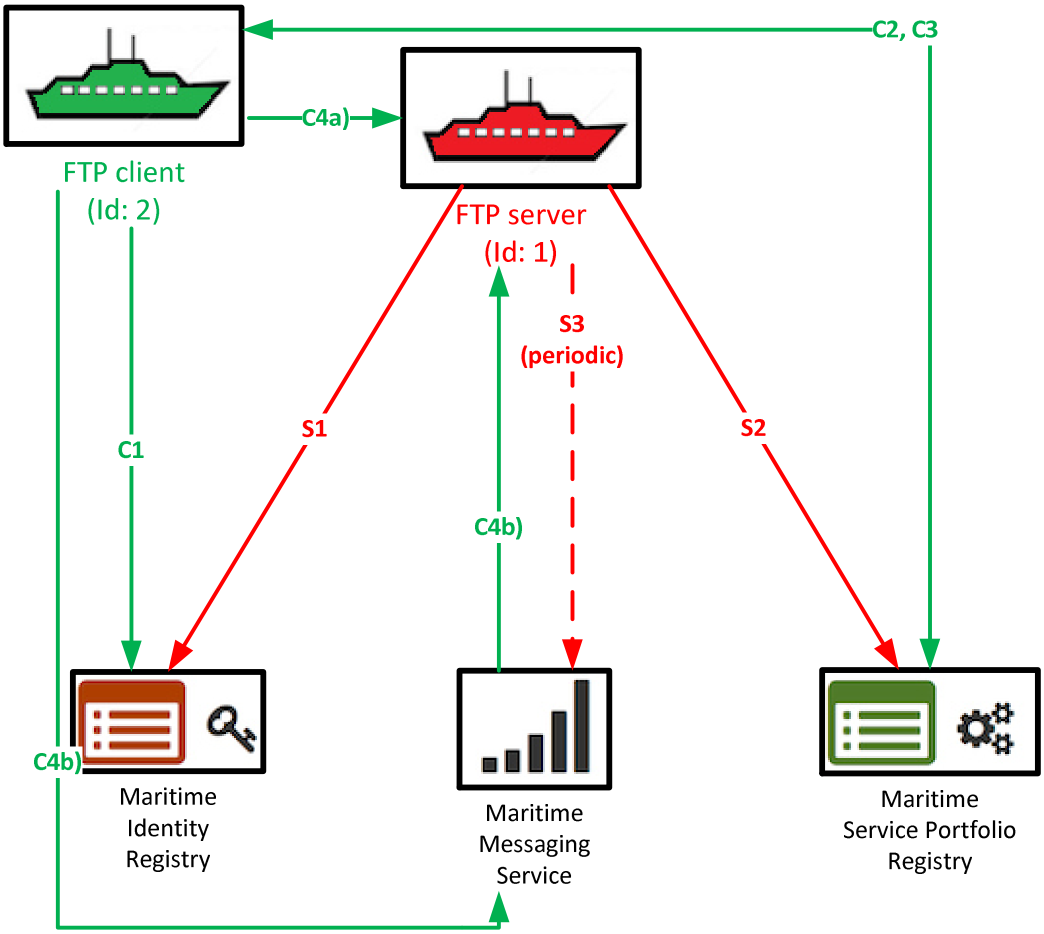

Fig. 17. Registration in the Maritime Cloud and the lifecycle of the Maritime FTP service

Below, the procedure contained in fig. 17 is explained more thoroughly (S1, S2,… etc. refer to the arrows in fig. 17).

<u>Maritime FTP – server (represented by red arrows in fig. 17):</u>

S1: Actor's registration in the Maritime Identity Registry

S2: The FTP server service registration in the Maritime Service Portfolio Registry

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a) endpoint FTP

b) endpoint MMS

S3: Periodic connections with the server (position data update, etc.)

<u>Maritime FTP – client (represented by green arrows in fig. 17):</u>

C1: Actor's registration in the Maritime Identity Registry

C2: Update of the Almanac

C3: Searching for the Maritime FTP service

C4: If there exists a compatible, active radio link:

a) connect using FTP

b) otherwise connect using Endpoint MMS

After the analysis of the documentation and the sample algorithm of the Maritime FTP service lifecycle (see fig. 17), the benefits of the Maritime Cloud have been identified. The list of those benefits can be divided into two categories, depending on the way the service is carried out.

The benefits of the Maritime Cloud when connection is made via the central server are as follows:

- Access to local and global services,
- Queuing of the transmitted data while the recipient is unavailable,
- Possibility to utilize geocasting,
- Full and up-to-date knowledge about other Maritime Cloud users,
- Ability to provide up-to-date information about our own state (to be used by other actors).

The benefits of the Maritime Cloud when connection via the central server is not possible are as follows:

- Access to local services stored in the Almanac,
- Possibility to update information about other MC users, under the condition somebody will locally provide us with those data.

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6 Seamless Roaming concept

In the following chapter, the concept of Seamless Roaming will be introduced. Seamless Roaming is a mechanism in which the most suitable (for the given service in the given time and place) radio link (interface) is selected from among all that are available at the vessel. The main task of the Seamless Roaming is a constant monitoring of the available radio links and switching between them to ensure optimal (given the selected set of criteria) conditions for the required maritime services. The Seamless Roaming algorithm will also address user's preferences, e.g. minimization of the transmission duration or minimization of the transmission costs.

Below, the Seamless Roaming algorithm will be thoroughly described, including its major components: the network monitoring entity and the radio link selection block. The proposition of the weighting radio link selection algorithm, which will consider the service's requirements and user's preferences, will be presented as well. At the end of this section, sample scenarios of the Seamless Roaming (for defined services and priorities) will be discussed.

6.1 Seamless Roaming algorithm

The Seamless Roaming will work according to the algorithm developed by the authors and presented in fig. 18.

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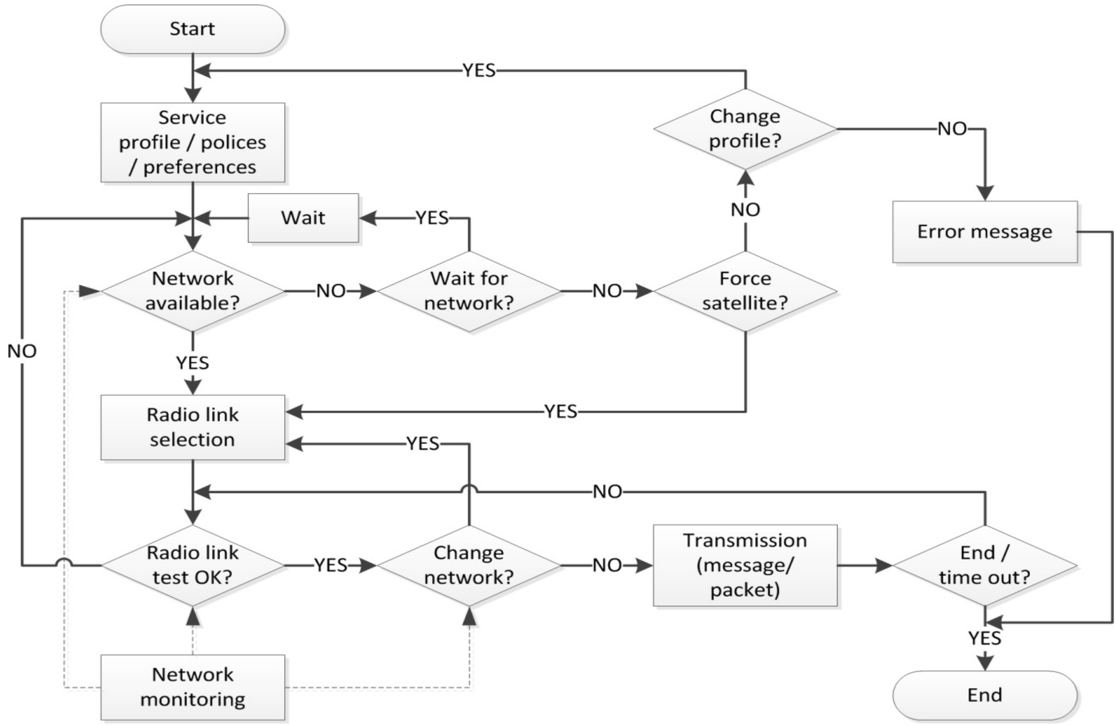

Fig. 18. General algorithm of the Seamless Roaming mechanism

The first step of the algorithm presented in fig. 18 is the initial selection of the radio network/system that may be suitable for the given service. This initial selection is done on the basis of the service's profile, implemented policies and/or user's preferences. After that, the availability of those networks/systems is verified, which is followed by setting up the actual connection to enable and initiate the service required by the user. An example of how the typical Seamless Roaming mechanism is executed is presented in fig. 19.

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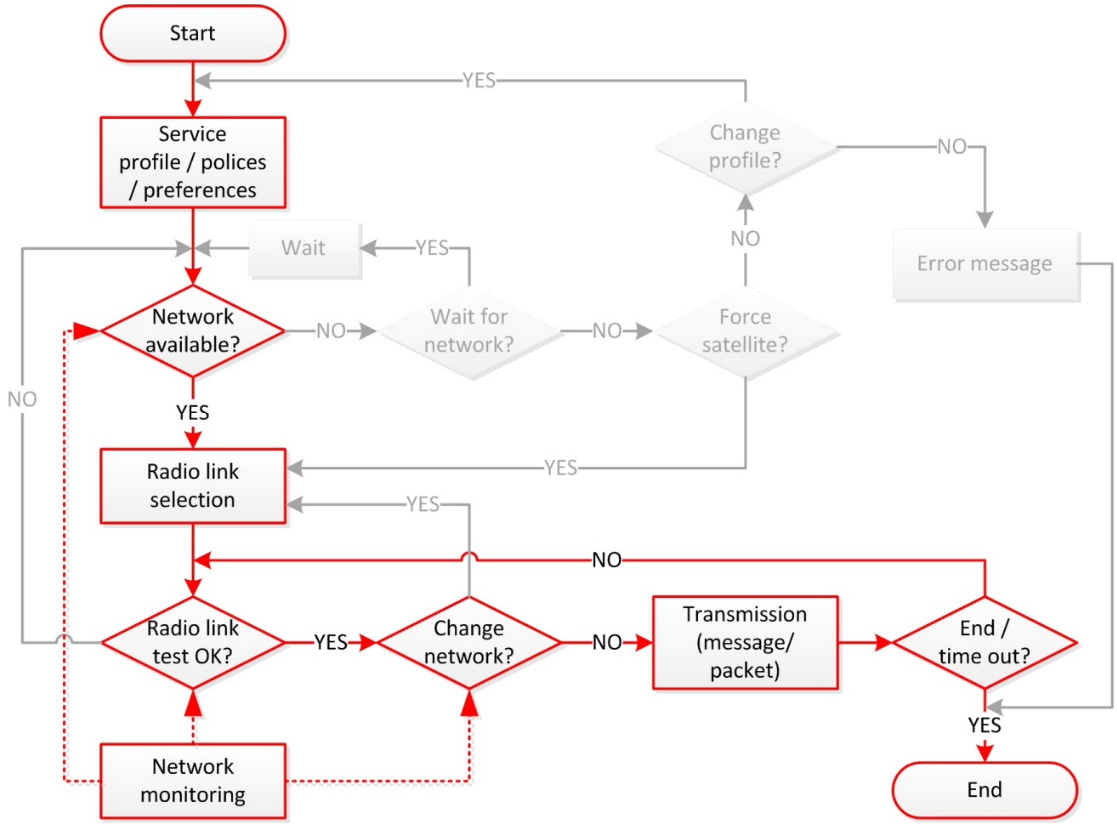

Fig. 19. An example of the Seamless Roaming mechanism

During the transmission, its quality is periodically measured and if necessary, a switching might take place (i.e. the network/system currently utilized might be replaced by another network/system in order to improve transmission quality or to ensure the initial quality criteria can be satisfied). The frequency of those tests may depend on the frequency of packets/messages transmission or it may be constant. If the network monitoring entity determines the network switching should occur, the algorithm will carry out this order. If during the transmission its quality drops so dramatically that the current service cannot go on (e.g. a vessel goes beyond the range of the terrestrial systems), then the availability of all radio networks/systems has to be rechecked. If – at a certain moment – none of those networks is available but additional information (e.g. from the GPS) indicates our vessel should shortly restore its connection with terrestrial systems (or the ship-to-ship communication can be employed), the algorithm may go into standby mode until the connection is actually restored. On the other hand, if the service has a high priority and no delays are acceptable, the transmission could be realized via satellite links which are available almost at all times (but at the same time they also very expensive and for this reason are not a viable option in typical scenarios). If the service's preferences explicitly prohibit utilizing satellite links, the algorithm will inform the user about the possibility of changing those preferences or will report transmission error.

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6.2 Network monitoring entity

The network monitoring entity is an important component of the Seamless Roaming mechanism and it is responsible for periodic quality tests of the available communication systems. The monitoring of the radio links is conducted both during data transmission (i.e. when a service is being carried out) and when the system is in stand-by mode (waiting for another task). The frequency of those tests will depend on the radio system type, utilized equipment, etc. For complex systems that are capable of switching between different radio links, only a single link quality assessment will be performed.

The radio links testing will be based mainly on the measurement of radio signal level and on the analysis of the broadcasted network quality parameters (which can be obtained without setting up the actual connection with the network). In case of satellite systems, the capability of setting up the connection using satellite links depends on the current ship's location, so the testing of those links simply comes down to verifying if the ship can be "seen" by satellites of the analyzed system.

The information provided by the network monitoring entity are used to make decisions by the radio link selection block, which is described below.

It should also be added, the information provided by the network monitoring entity might give knowledge about the 'neighbors' and the quality of their connections. The term 'neighbors' is very general and in this case might have several meanings: it could represent a nearby ship, a nearby base station or any relevant element of the radiocommunication link. The knowledge of the neighbors and their current state allows to develop relevant self-organization and routing algorithms, and consequently to implement mesh network-based solutions which potentially could prove advantageous for the future hybrid communication system.

6.3 Radio link selection

Alongside the network monitoring entity, the radio link selection is a second major element of the Seamless Roaming mechanism. Generally, it is responsible for selecting the optimal method of transmission in the given time and place on the basis of the information on networks' availability and performance (provided by the network monitoring entity) and then – if required – for switching between various data transmission technologies. It should be underlined, the procedure of radio link selection and (perhaps) switching will be carried out periodically during the connection (not just once when the connection is set up), because the availability and quality of radio networks will vary both in time and place.

From the Maritime Cloud point of view, the radio link selection mechanism will decide which *endpoint* will be used for the connection.

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For the implementation of the discussed block it is crucial to establish link selection criteria, as they will serve as a base for every decision about selection/switching of the radio link. The radio link selection criteria that have been defined up to this point are as follows:

- Radio signal power level,
- Data rate,
- Transmission delay,
- Predicted duration of the link availability,
- Required (maximum) time during which data must be transmitted,
- Amount of data to be transmitted,
- Transmission costs,
- Priorities of the service/user,
- Defined list of endpoints for a given service.

The above information – or at least some of them – will serve as an input to the link selection algorithm that is being developed now and whose initial concept is presented in the next section.

It should be noted that one of the issues that might arise during the channel switching is the overhead, i.e. the time required to establish a new connection. In some scenarios this overhead might be unacceptably long, making the whole concept of switching virtually useless. One of the options to counter this effect is to keep all the available connections, while obviously using only one of them. For example, let us assume a ship in a given moment of time is in the range of both the WiFi network and the 3G network. For the purpose of transmission the ship utilizes the WiFi, but it also maintains the connection with the 3G network. Consequently, when the ship moves out of range of the WiFi, the process of switching to 3G will be very fast and the whole overhead will be kept to a minimum.

6.4 Weighting algorithm of the radio link selection – general concept

For a set of various maritime services (and also for the same service utilized by different users with different preferences) some radio link selection criteria may be more important than the others. For this reason it has been decided the most suitable solution will be a weighting radio link selection algorithm.

The main assumption of this concept is that both the user and the services have priorities and preferences that should be processed by the algorithm. (It should be underlined, though, that in order to utilize a service, it is necessary to have an active link from among those defined as endpoints for this service.) Obviously, not all of those priorities and preferences have to be equally important. Consequently, for a certain service, a set of most important parameters

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(from among the radio link selection criteria) will be defined, and then each of those parameters will be assigned a weight coefficient. Additionally, to give user more freedom, it will be possible to modify (within reasonable limits) some of those parameters.

The weight coefficients will be obtained empirically during the implementation phase. Additionally, a metric will be developed, to facilitate a final decision which of the available radio links is the most suitable for a given application.

Examples

- Scenario 1 – service: data transmission, priority: minimum transmission costs.

  Key parameters and their respective weight coefficients:

  - Transmission costs – 0.6;
  - Predicted duration of the link availability – 0.2;
  - Data rate – 0.1;
  - Radio signal power level – 0.1.

- Scenario 2 – service: data transmission (large file), priority: maximum data rate.

  Key parameters and their respective weight coefficients:

  - Data rate – 0.6;
  - Predicted duration of the link availability – 0.2;
  - Radio signal power level – 0.1;
  - Transmission costs – 0.1.

- Scenario 3 – service: data transmission (small file), priority: minimum transmission duration.

  Key parameters and their respective weight coefficients:

  - Predicted duration of the link availability – 0.7;
  - Data rate – 0.2;
  - Radio signal power level – 0.1.

It should be noted that if the predicted duration of the link availability has a higher priority (i.e. bigger weight) than the data rate, then the system can select e.g. the VDES system, even though the UMTS might be available as well, because the VDES link will be available longer and there is much smaller risk that the radio link switching during transmission will be necessary.

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6.5 Sample scenario

In the following section, a sample scenario of the Seamless Roaming mechanism will be presented. The scenario refers to a ferry voyage from Gdynia to Karlskrona. In fig. 20, circles represent the approximate ranges (at sea) of systems:

- LTE (green circles),
- UMTS (blue circles),
- VDES (red circles).

The arrangement of the respective base stations does not correspond to the actual terrestrial infrastructure of those systems, it is only to illustrate the hypothetical zones of their ranges. Assuming the typical parameters of these systems' base stations and user terminals, the approximate ranges were calculated, yielding the following results: **25 km for LTE, 45 km for UMTS and 70 km for VDES**. The points labeled in fig. 20 as "1" to "8" represent subsequent steps of the Seamless Roaming algorithm.

Let us assume, it is required to keep the highest data rate possible along the whole route from Gdynia to Karlskrona. The voyage starts at point "1" (Port of Gdynia), where the ship establishes connection with the terrestrial LTE system. This connection is maintained as the ship moves through the Bay of Gdansk and along the shoreline – until it reaches point "2". At this point, a switching to UMTS takes place, because the ship is not in the LTE range any more. Point "3" indicates the "borderline" of the UMTS range, so another switching – to VDES – takes place there. When the ferry gets to point "4" (i.e. the "borderline" of the VDES range), the user can decide – unless he has done it before – (a) if the service should be stopped till the connection with terrestrial systems is possible again or (b) if the service should be continued using satellite links. In the next steps – as the vessel approaches land – the switching will take place in a reverse order: first to VDES (point "5"), then to UMTS (point "6") and then to LTE (point "7"). The connection with LTE will be maintained till the end of the cruise, i.e. to point "8", which is the ferry's final destination (Port in Karlskrona).

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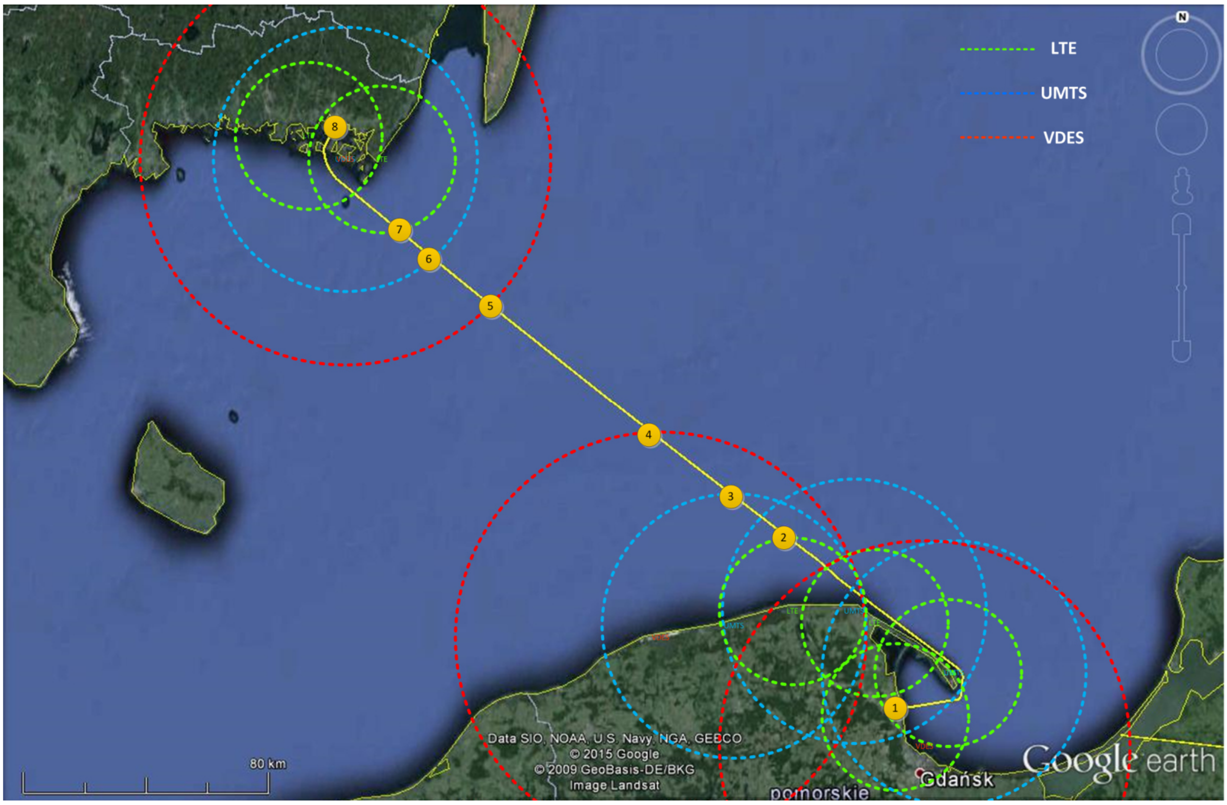

Fig. 20. Approximate ranges of the terrestrial radiocommunication systems along the ferry route from Gdynia to Karlskrona.

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