Data Transmission System Architecture for e-Navigation

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Abstract. The subject of research is the modeling of data consistent with the objectives of the e-Navigation concept. Author presents general aspects of data transmissions in maritime transportation. He shows possible directions of communication and connection methods and identify the problems arising from the application of specific solutions for individual transmission paths. Author presents also a prototype architecture of the e-Navigation concept tested during the EfficienSea project and an original concept of structure in line with the idea of "OneWindow" contact point.

Keywords: e–Navigation, EfficienSea project, radio-communication.

1 Introduction

Maritime communication and data transmission in maritime transportation are widely discussed at the work on e-Navigation concept. There is a big difference between the technological capabilities available on board the ships (e.g. satellite Internet connection), and the systems required by regulations – Global Maritime Distress Safety System (GMDSS). In addition, the duty officer is burdened with unnecessary sending thousands of kilobytes of data, often available from other sources. On the other hand, most of the solutions used in a communication system is obsolete. Exchange of information between ship and shore is now a natural and necessary procedure to manage vessel in a safe manner. Unfortunately, it is believed that the existing GMDSS is in some ways an archaic system and cannot deal with modern communication requirements. Users have a constant access to new technologies and they are putting pressure on the administration to change regulations when it comes to communication and data transmission at sea. We need to change the rules and create a new data exchange system that will modernize and streamline data transmission in maritime transport. The idea of e-Navigation is a solution that not only improve communication, but also provides a number of useful features for both group of users, this ones on shore and this ones on the ship [9,11].

2 e-Navigation

e-Navigation is a concept developed under the auspices of the International Maritime Organization (IMO) in order to improve the safety of navigation of commercial

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vessels through better management of data structures on ships and ashore, better exchange of data between ships and authorized land stations (e.g. Vessel Traffic Services, VTS stations) and reliable communications between them. The definition of e-Navigation proposed by International Association of Marine Aids to Navigation and Lighthouse Authorities(IALA), it is generally accepted, the initial definition of the emerging system [4].

"e-Navigation is the harmonized collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment."

Another identified problem is an enormous amount of information which Officer Of the Watch (OOW) has to process and interpret. The need for standardization and integration is a natural consequence of the introduction of new technologies. An example of the integration of systems can be Integrated Bridge Systems (IBS) or Integrated Navigation Systems (INS). Unfortunately this systems are limited, to devices available on board the vessel. e-Navigation in its assumptions, is a concept that treats maritime transport in a holistic way. That means that one of the goals is to integrate, standardize and automate the exchange of information between ship and shore, between two ships and between shore users as well. e-Navigation is not limited to data concerning only the vessel and sea environment but the scope of the system includes also authorized shore users. It must be remembered that the land is the starting and ending point of each sea voyage and it is obvious that shore structures are important part of maritime industry [2, 10].

3 Data Transmission Directions in Sea Transportation

Radio-communication systems for maritime transport, due to the nature of this brunch of industry, should provide effective and constant connection. There are four directions of the flow of data in shipping [5]:

- ship-shore,
- shore-ship,
- ship-ship,
- shore-shore.

Due to the nature of transmitted data, it have to be chosen a method of communication. It have to be specified how users can establish communications and transmit data. For each of the four directions mentioned above, we can identify three ways of data transmissions [5]:

- pull - request for messages, data is transmitted from sender X to recipient Y but flow is initiated by recipient Y. An example of this type of transmission is communication between a client and server in a typical TCP/IP network,

- push adressed – sending addressed messages, data is sent from sender X to a specified recipient Y. An example would be sending SMS via mobile phone or sending addressed messages via AIS (Automatic Identification System) device,
- push-multicast - data is sent by the sender X to multiple recipients Y. An example would be Navtex, radio and AIS messages. This method sends data to a group of recipients simultaneously in a single transmission. A special case is broadcasting, when a group Y consist of all possible recipients.

Table 1. Directions and methods of data transmissions in maritime transport [5]

	Pull	***Push-addressed***	***Push-multicast***
Ship → Shore	Data pulled from ship on shore initiative.	Data pushed from ship to single component on shore.	Data pushed from ship to multiple components on shore.
Shore→Ship	Data pulled from shore server by ship.	Data pushed from shore to a single ship.	Data pushed from shore to multiple ships.
Ship→Ship	Data pulled from ship on other ships initiative.	Data pushed from ship to another ship.	Data pushed from ship to multiple ships.
Shore →Shore	Data pulled from shore component to other shore component.	Data pushed from shore component to another shore component.	Data pushed from shore component to multiple other shore components.

When creating system to enable the connection in the above mentioned directions and using mentioned methods, there are three aspects which have to be considerated. Firstly, communication systems often provide connectivity in several directions, such as by using different protocol (e.g. AIS data can be transmitted in land-to-ship relations, ship-to-ship and ship-to-shore). Secondly, the use of different communication systems often gives different transmission characteristics (e.g. both the Internet and the AIS can be used as a communications system and to provide data from ship to shore, but both of these solutions have very different characteristics in terms of capacity and reliability). Thirdly, there is no communication system that would allow transmission in all directions to all above-mentioned methods. There is a need to create a new system using new techniques of data transmissions or a system that would effectively integrate currently existing transmission techniques [6].

4 Data Transmission System Architecture – EfficienSea Project

EfficienSea is a project of the European Union regarding the safety and vessel traffic in the Baltic Sea. One of the working groups, dealing with the issue of e-Navigation, has developed a prototype of the system architecture. In this chapter there are assumptions of the project and a chart scheme of system architecture. There are also some conclusions which are results of research carried out on the possibility of using different methods of communication in e-Navigation.

4.1 Ship Infrastructure

Facilities on board consists of software that runs in the Windows environment. The program is called an e-Navigation Enhanced INS (ee-INS). This software is free and available with source code. This gives possibility to change or modify software by programmers. In addition, display chart systems is based on the OpenMap license. It is an open platform that is the source of maps (no navigational), which are displayed on the user's monitor. Commercial plug-ins allow to use Electronic Navigational Charts (ENC), but they are not necessary for purpose to test data links. The application has a few basic navigation functions. Personal Computer (PC)is connected to the Internet through Multi-WAN router, but also has a connection to the AIS. The structure of the prototype is consistent with the objectives of the IMO regarding development of e - Navigation, see Fig. 1 [5].

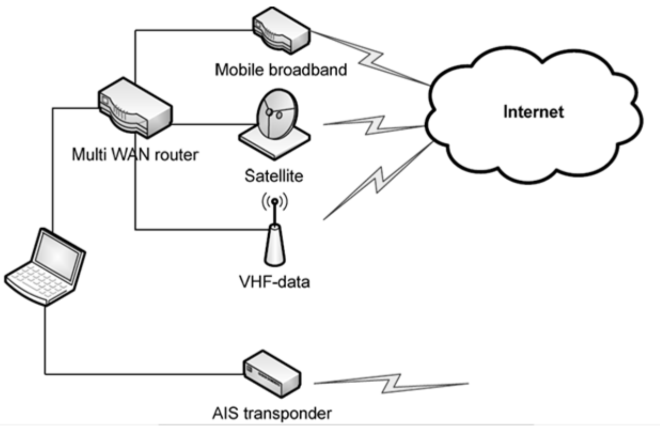

Fig. 1. Ship infrastructure[5]

In this approach, conception of architecture of a new system includes three different Internet connections:

- mobile broadband,
- satellite communication,
- data transmission via VHF

and AIS as a complementary system or back up in the situation of failure of Internet connection.

4.2 Shore Infrastructure

The infrastructure on the land consists of the following components: the e-Navigation server, VTS stations and land based AIS. The elements on the land are connected via Internet. E-Navigation Server provides connectivity compatible with request-response method of connection. This structure allows to use Internet on the ship and VTS stations. The server uses land based AIS network to send and receive AIS messages.

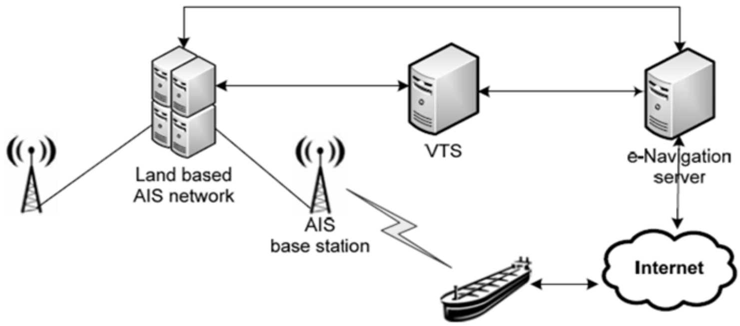

Fig. 2. Shore infrastructure [5]

The structure of the prototype is consistent with the objectives of the IMO regarding the e-Navigation, see Fig. 2 [5].

e-Navigation server in proposed concept allows creators of the system to use the various services that will be available in e-Navigation Fig. 2. Software applications are available through online services and, in some cases, through the Internet overlay (data can be displayed and entered by the user). Computer programs are dependent on multiple data sources, such as hydro-meteorological and oceanographic data, weather forecasts and data from the AIS. Most of these sources are separate and independent services. The acquired data are stored on separate servers, and e-Navigation server is used as a “One Window” contact point for easy access to the data. Thanks to this service regulations may be distributed across multiple physical servers. This is the so-called Service Oriented Architecture (SOA). Distributed server network not only provides faster data access (prevents server overload), but also provides a level of redundancy in case of failure of one of the servers [1].

As a web services protocol were chosen XML-RPC protocol and HTTP protocol. XML-RPC is better suited to SOA because it is simpler and data models (questions and answers) can easily be converted to XSD (XML Schema, Schema Extensible Markup Language) rather than to the WSDL (Web Services Description Language). XML is used to query and response in a client-server relation, and the HTTP protocol is used to transport the data [5].

5 Data Transmission System Architecture – Author’s Proposition

There is believe that one of the main tasks of e-Navigation concept is the exchange and storage of data. To ensure effective exchange of information, the structure of the system must be composed of elements on the ship and land based infrastructure. EfficienSea working group dealing with the issue of e-Navigation has created a proposal for the structure of the system (Fig. 1 and Fig. 2). Author creating his own infrastructure diagram tried to use a different approach. Basing on the international regulations and his professional knowledge he tried to identify information that is now transmitted in maritime transport. Later on he created information flow paths between different users and create a project of system structure. In Fig. 3 and Fig. 4. author presents his own vision for the structure of the system. The chart diagrams shows the main elements of both structures on the land and on the ship. There are also symbolically presented directions in which the data will be transmitted. There is also emphasized need for a “One Window” contact point (both on board and on shore).

5.1 Shore Infrastructure

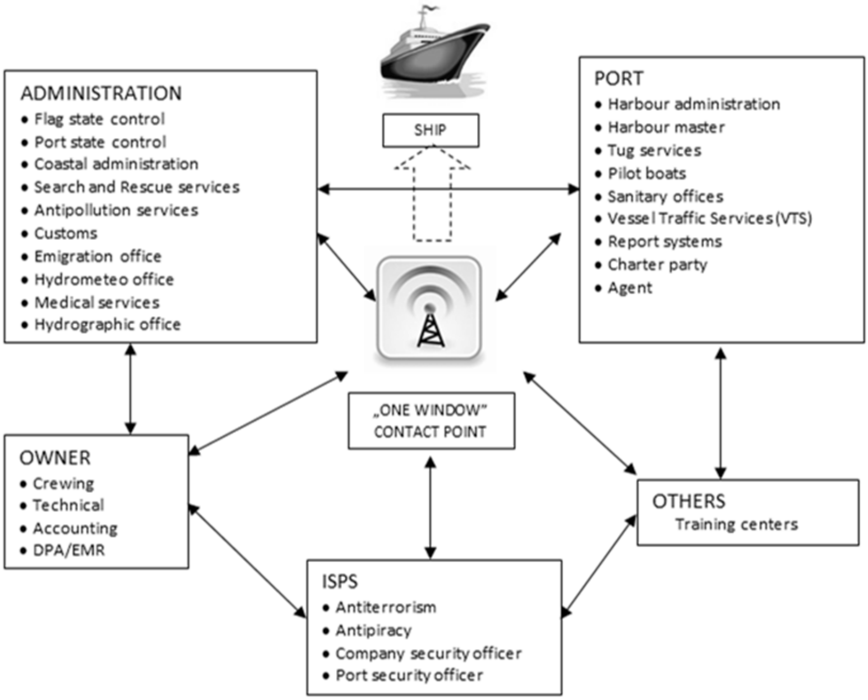

Fig. 3. Shore infrastructure

In Fig.3 there are indicated land users with which a ship currently exchanging data. It is also shown how authorized land users can obtain ship data using “One Window” contact point. That point may be one of the servers on which the data would be collected and archived. As the creators of the EfficienSea project author believes that the distribution of servers allow for better and faster exchange of data and provide a level of redundancy in case of failure of one of them. Currently in Poland there is under construction National System of Maritime Safety(KSBM, Krajowy System Bezpieczeństwa Morskiego). There will be three centers, one for each Maritime Office, which can be treated as a “One Window” contact points. User will have possibility to get information stored on KSBM servers thanks to SWIŻB software (System Wymiany Informacji Bezpieczeństwa Żeglugi, Maritime Safety Information Exchange System) [8]. As shown in Fig. 3 land users are also able to exchange data directly with each other. Because the Internet provides connectivity in shore-shore relation, possibility to exchange information directly between users ashore will reduce the server load, speed up the exchange of data. There is also a risk because data is not verified in "One Window" contact point and may be inaccurate or even false [1].

5.2 Ship Infrastructure

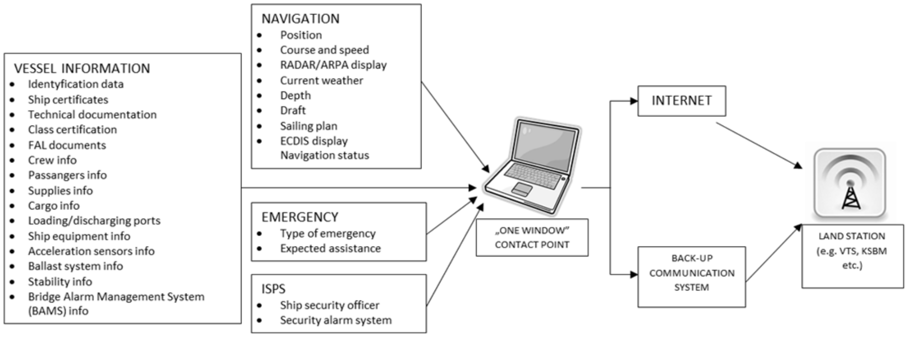

Fig. 4. Ship infrastructure

Figure 4 shows schematically a vessel network which allows easy and fast exchange of information and data. The diagram presents categories of information that ship exchanges with other users. All data is collected in a "One Window" contact point. A point on the vessel may be a ship's server or a VDR device appropriately adapted for this purpose. The data is then sent to the authorized land user (e.g. VTS), where data are collected, archived, reviewed and possibly shared with other authorized users [7].

Transmission is possible through the use of satellite Internet connection. Detailed analysis shows that the Internet offers the possibility of access to a large number of services that have been defined in concept development of e-Navigation. In addition, through the use of diverse Internet software system has ability to adapt to changing conditions and user needs. However, as mentioned earlier, does not provide communications in all directions and to all methods listed in Table 1, which is why it is necessary to use other means of communication such as AIS. This is consistent with EfficienSea project. AIS has in its message structure an empty space which developers assumptions were intended for use in new systems. Such a system could be e-Navigation [3].

6 Evaluation of System Architecture

The following are the conclusions and findings to a large extent on an EfficienSea research. During testing data transmission links as shown in Fig. 1 and Fig.2, there have been identified some problems, and the observations which are presented below. Author basing on the differences and similarities between his concept and EfficienSea project tries to predict what problems may arise in the future, and what solutions can deliver measurable results.

6.1 Assessment of EfficienSea Project

Data Modeling and Coding

The process of describing the data transmitted using UML and transform it into an XML schema definition (XSD) was simple and effective. Using XML protocol for data encoding introduced to increase the amount of data due to the markers and a textual representation of the number as opposed to the binary encoding. The use of compression for HTTP-enabled significantly reduce the amount of transmitted data [5].

Communication via Internet

Internet has proven to be an effective method of communication in relations shore→ ship (push) and shore → ship (pull). Polling is an effective solution in relation shore → ship (push), but it has some significant drawbacks caused by delay for the polling interval, which is not acceptable for some services, such as coordination of SAR (Search and Rescue) action. Delay in communication in distress is also inconsistent with the provisions of Chapter V of SOLAS Convention (Safety of Life at Sea).

The bandwidth of each of the three ways to connect to the Internet used in the test proved to be sufficient for the purposes of testing prototype. Answers to websites and establish the connection did not last longer than 10 seconds. Of course, the question arises whether the connection will be sufficient for large data packets? There is a belief that communication via satellite is too expensive, via VHF is to slow and via mobile phones available only near the shore [5].

Communication via AIS

AIS proved appropriate for periodic transmission of small packets message. For more complex tasks AIS limits reduced communication. It was found that the use of AIS to communications between vessels was quite reliable. Using the base stations to send and receive messages were less reliable because they depend on the distance from the base station, and the characteristics of the station [5].

Ship Infrastructure

Ship devices allow you to connect additional external PC via the pilot plug. Using pilot plug on the bridge of the ship turned out to be more difficult than previously expected. Quite often plug for the pilot was not properly connected or not connected at all. In addition, the challenge was to connect the remote control plugs into the computer. Finally used equipment that connect to Wi-Fi. To connect to the Internet uses a simple router (Multi-WAN router). Failover when one connection becomes inactive, causing problems due to the delay resulting from the switch from one system to another. When the connection is not available, such as mobile broadband connection status can vary considerably over a period of time. At the end of the call is eventually lost. This can lead to frequent changes in the type of calls at the time. It is believed that more advanced routers installed on the ship would operate better [5].

Shore Infrastructure

Using the Internet and standard software components as Web pages, application servers and databases did not cause major problems. Only one server-side land-based infrastructure has been shown that in order to achieve high reliability of the system, individual servers should be avoided in the future [5].

6.2 Conclusion on the Author's System Architecture

Internet well suited as a data transmission system in relation land-land and land-to-ship, ship-to-shore, while the poor ship-to-ship. The author suggests that the communications ship-to-ship can be replaced, to some extent, by communications ship-shore-shore-ship. Data transmission via land based servers (PCs) would not only transfer large data packets, but also allow for their review and possible protection against unauthorized access. Currently, access to information like position, speed and course of the ship can get everyone in Internet. Authorized and properly protected land access to the servers allow control over the outflow of data. Currently, the exchange of data in ship-to-ship is limited to the transmission of AIS and VHF voice. Both systems work in the same frequency and are characterized by a relatively small range of approximately 30 nautical miles. Both systems should remain for fast communication in a range of coastal stations and between vessels.

7 Conclusion

Suitable systems for communication are essential to ensure effective and efficient communication in e-Navigation. There is believe that one method of communication is not enough, because each of the currently existing methods will behave differently depending on what and where is transmitted and what effect you want to achieve. Author and EfficienSea working group, they proposed usage of two transmission methods AIS and Internet. Each of these methods has certain advantages but also limitations. In EfficienSeaproject AIS and Internet are equivalent means of transmission, however, the author believes that the Internet should be the primary way communication and AIS should be considered as a back-up system. Capacity, transmission speed, reliability and topology are some of the parameters that determine the effectiveness of the system in particular transmission. Main goal of tests carried out during the EfficienSea project and research in the Faculty of Navigation of Gdynia Maritime University was to select the communication method and use it in e-Navigation. Second aim was to identify what system may be needed in the future, because there is no doubt that the existing systems (especially the minimum required by regulations) are not sufficient.

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