



## **MONALISA 2 0\_D2.3.1-5**

### **Systems Technical and Technology Description**



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## 1 Executive Summary

The focus of this technical report lies on listing the technical infrastructure needed for the Sea Traffic Management (STM) concept in order to enable it to assist the maritime traffic from port to port in the most efficient way by integrating all actors, actions and services. Sea Traffic Management includes concepts for Strategic Voyage Management (SVM), Dynamic Voyage Management (DVM), Flow Management (FM) and Port Collaborative Decision-Making (Port CDM) as well as Sea System Wide Information Management (SeaSWIM) as infrastructural concept for communication. Definition of the new route exchange format as one of the components of the ECDIS standard IEC-61174 edition 4, which was accepted in august 2015 as one of the outcomes of the MONALISA projects is a big step toward the realisation of STM. These subconcepts each provide specific services, most of which do not exist in this form today. For the development and furthermore for the realisation and implementation of these services, it is necessary to understand the possibilities and the limits of the current technical infrastructure.

To implement the STM target concept, the maritime world has to face many challenges regarding its technical infrastructure in all three main instances: ashore, onboard and regarding the available communication channels. In the era of highly connected systems and massive information exchange through various different channels and systems, it is very important to define clear requirements for not only existing but also for new required technical systems. Considering the resulting improvements, bringing the right information to the right actor at the right time in a network where broadband is quite expensive and many of the devices needed for information exchange are not connected efficiently or not used at all, is a challenge worth accepting. The creation of a new technological framework may be needed in some cases but this is not easily achieved and outside the scope of STM. Nevertheless it is important to notice that (internet) access via sufficient communication link is a prerequisite or a boundary condition for STM Services.

Unreliable and highly dependent on weather condition voice communication with ships via HF needs to be replaced by communication systems with higher bandwidth and reliable connectivity. Satellites can provide immediate and reliable communications using voice, telex or data channels. The operation continuity of a satellite communication network under conditions that sometimes render other methods of communication inoperable, is one of the main reasons for using satellite communication as technical infrastructure for STM.

Maritime VSat Technology with its cheap and small antennas is a very good basis for the technical infrastructure of STM. VSat antennas with diameters less than 2 m are cheap and can be installed everywhere. This makes it economic to use them in systems where a large number of terminals is needed, as in shipping. Nowadays VSat is using IP-based time division multiplexing that dynamically allocate bandwidth for each ship.

Generally the “network” bandwidth should be available when STM Services need it and the technical infrastructure should guarantee that the access point does not



become a bottleneck. Dedicated bandwidth (SCPC) fulfils the discussed requirements of the STM Services, but on one hand it is too expensive as the client buys its own part of the satellite and on the other hand it makes a highly inefficient use of the bandwidth: We suppose that STM Services will not require the whole bandwidth all the time and the part of it being not used (idle) is wasted. Therefore it is more cost efficient to use shared bandwidth. Nowadays with IP-based time division multiple access technology bandwidth is dynamically allocated bandwidth to each ship for shared bandwidth. Oversubscription enables an efficient and cheap usage of the given bandwidth.

Shipping has not dealt enough with communication security and must be taken into account in the future. It should be seen not only as a technical aspect but also as an operational one. Each new port and interface to the ship's systems opens creates a new platform for hackers and attackers to search for vulnerabilities and attack the systems. It is very important therefore for the technical infrastructure as physical and logical enabler for STM Services to provide them with appropriate security. The technical infrastructure of STM can be attacked at many different levels as listed in (ENISA, 2011) e.g:

- Satellite communications
- Automatic tracking system
- Marine radar system
- Electronic chart display information system

Services using these systems can be attacked as well. The information security is not any more a problem of the land based systems. Shipping industry must incorporate proper defense in depth strategies to handle cyber threats(12). STM and SeaSWIM with their services taking into account the information security risks will increase information security in shipping.

STM services will be implemented by a combination of on-board based services and shore-based service providers (using SeaSWIM connectors), which upholds the voyage related information for land based SeaSWIM information consumers. Open interfaces and open interface standards must be introduced in order to enable more effective communication as well as innovative competition between service providers.

Since shipping due to its slow change ability, over foreseeable future, STM services must be able to distribute over a wide range of communication technologies. Therefore is the Integration in current existing systems a must.

Bring your own Service (BYOS) on board should be possible without major changes in the technical infrastructure and taking into account the limitations in bandwidth and the expensive connectivity.

The main fields of STM's requirements for the technical infrastructure are the following:



1. Reliable communication channels
2. Information Security
3. Open interface standards
4. Integration in the existing technologies and making use of the latest development in the maritime technology

The usage of the STM Services will lead to necessary changes in the technical infrastructure, but the first step toward STM and its advantages consists of changes in the technical infrastructure as e.g. appropriate connection quality and bandwidth to exchange information with the land based stations.



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## 1 Introduction

### 1.1 Background

Sea Traffic Management (STM) is the dynamic, integrated management of sea traffic and maritime space (including sea traffic services, management of the maritime space and sea traffic flow management) through the provision of facilities and seamless services in collaboration with all parties and involving seaborne and shore-based functions. STM contributes to improved safety, environmental performance and efficiency in the maritime society. In other words it is a holistic approach to distributed service related to the berth-to-berth voyage enabling the efficient, safe, and environmentally sustainable sea transport.

STM is based on five main concepts:

- Strategic and Dynamic Voyage Management (SVM and DVM)
- Flow Management (FM)
- Port Collaborative Decision Making (Port CDM)
- Sea System Wide Information Management (SeaSWIM)

These concepts fall in two main categories:

- Operational concepts: SVM, DVM, FM and Port CDM
- Service oriented communication infrastructure concept: SeaSWIM as enabler for the operational concept

All these STM subconcepts will provide specific services, which do not exist in this form today. Definition of the new route exchange format as one of the components of the ECDIS standard IEC-61174 edition 4, which was accepted in august 2015 as one of the outcomes of the MONALISA projects is a big step toward the realisation of STM. but the technical implementation is the crucial factor of its success. As stated in a current situation analysis regarding amongst other views also the technology view of STM, most of the communication and navigation systems are “closed” in the sense that they are not using open interface standards needed to bring forward the maritime service infrastructure described above. Despite the rapid development of communication technology in recent years, the maritime world does not profit from its advantages since it still relies on outdated technology, which is insufficient from an information security aspect.

### 1.2 Scope

Although these concepts are being defined in the MONA LISA2.0 under the assumption of having full connectivity for information exchange to enable their independence from the technical systems, an overview of the existing, from STM required and missing technical infrastructure is of very high importance and is the main goal of this report. Shipping needs to tap into the information flow by



realization of these concepts which bring their own requirements on the technical infrastructure. For the development and evolution of STM and the SeaSWIM concept as information exchange enabler, it is crucial to analyze how the existing technical infrastructure operates and what gaps are to be filled in order to comply with the requirements of STM. Information security aspect of the technical infrastructure has to be considered as it plays a key role in the success of whole STM and federative approach of SeaSWIM.

It is not possible and out of the scope of the MONALISA 2.0 project to modernize the whole technical infrastructure. The recognition of outdated parts of the technological infrastructure in the maritime world would be a step toward a clear picture of the current situation, enabling a clear definition of future needs of the different STM services classified by the subconcepts of STM. The decision if a system or part of the maritime technical infrastructure should be classified as an outdated one is made based on its ability to transmit data and to provide the data for a desired service in a specific form. The tradeoff between replacing outdated systems and developing systems that enable capturing of data from outdated systems in a way that can support STM services should deliver the basis for further decisions.

### **1.3 Proposed Solution**

This report contributes in giving an overview of actual navigation and communication systems and how they can fulfil STM requirements and the idea of bring your own service (BYOS) like:

- Reliable connectivity
- Higher bandwidth
- Higher information security
- Open standards to enable competition between suppliers of products (in our case STM Services) based on the standard.

## **2 Existing Technical Infrastructure and STM**

### **2.1 Navigation and Communication Systems**

A wide range of navigation and communication system can be found in the maritime world. It can be classified as the most heterogeneous industry from a technical systems point of view. The technical infrastructure on board varies from primitive VHF, MF and HF equipment, GMDSS, ECDIS, Radar, AIS to modern and expensive satellite communication. This wide range of technical system is characterized by lack of connectivity and open interfaces. This part consists of an overview of some of the existing technical systems and their relations to STM and its services.

Information exchange efficiency in the sense of STM can be improved exactly by defining standard for interfaces between the existing systems. Some of the systems offer more than one possibility of implementation and usage, e.g. satellite communications with different occurrences as VSat technology or fleet broadband or even different message types like in AIS. These possibilities can be found in the e-



Navigation gap analysis (eNavigation,2014) and (IMO, 2014)and in the Strategy Implementation Plan (SIP). A good matching and check on how STM addresses the e-navigation SIP should be further investigated to find out and clarify the relation to STM and its services.

### 2.1.1 ECDIS (Electronic Chart Display and Information System)

As described in the document Current Situation, there is no standard for navigation systems within the maritime industry; each planner's environment will therefore vary greatly between different actors who are taking different approaches to the same issues. A typical voyage planning tool available today is centred around the officer on the bridge. It is interfaced towards the ECDIS system, a technical system that fulfils all requirements of the International Maritime Organization (IMO) regarding its functionality and architecture, and usually features the following navigational charts and supporting systems:

- ENC (Electronic Navigational Chart) is a regionally limited extract from an official database containing digital navigational charts. It is rendered in compliance with the S-57 standard given by the International Hydrographic Organization (IHO) and it is encrypted for protection against illegal copying and changes.
- RNC (Raster Navigational Chart) is an official digital copy of nautical paper charts. It has fewer functionalities than an ENC, but is nonetheless allowed to be used officially for navigation purposes in case of missing or out of date ENCs.
- Paper charts can always be used.
- SENC (System Electronic Navigational Chart) is the mapped ENC in the processor of the ECDIS. The display functionalities and decryption of the encrypted ENCs in the system are done by proprietary code implemented by the ECDIS manufacturer.
- RCDS (Raster Chart Display System) reads out and displays RNCs.

The data is classified as official and private data. Official information is information generated by an authority while private data (information) does not originate from official sources even though it may use an official standard e.g. S-57.

Nowadays the maintenance and support for navigational charts is arranged in each company individually. ECDIS provides external private interfaces for ENC/RNC updates which can be used to further optimise the whole process of information exchange regarding navigation charts by communicating over open interfaces and digital data streams. ECDIS and navigational chart providers can benefit from the possibility to exchange their encrypted information directly with their own system on board through digital data streams and corresponding access rights.

ECDIS functionalities can be categorised into:

- **Chart work:** gathering and display of all related and up to date charts for the voyage.
- **Voyage Planning:** planning the route to be sailed and activating it.



- **Voyage Monitoring:** e.g. automated voyage monitoring after the threshold for ECDIS alarms has been set up.

ECDIS is a relative new and modern system on the bridge of ships and can be accessed easily with adequate open standard interfaces. Dynamic Voyage Management services as well as flow management services could use ECDIS for information exchange. Even the actual functionalities listed above can be bound to the other voyage relevant information over the voyage identifier, which is one of the core exchange format standards alongside with the route exchange format in STM. A basis for connection to an existing system is given. Open standard interfaces are in this case crucial for the realization of this important connection.

### 2.1.2 AIS (Automatic Identification System)

AIS is an automatic tracking system used on ships and by Ship Traffic Services (VTS) for the identification and locating of ships by electronically exchanging data with other nearby ships, AIS base stations, and satellites (International Telecommunication Union, 2014).

If satellites are used to detect AIS signatures then the term Satellite-AIS (S-AIS) is used. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for water transport.

The following data can be exchanged via the AIS:

- Dynamic information
  - Position of the ship (LAT, LON)
  - Course of the ship
  - Heading
  - Rate Of Turn (ROT)
  - Status
- Static information
  - IMO Number
  - Ship's Name
  - Ship's length and width
  - Ship's category
- Voyage oriented information
  - Next port and ETA (not updated automatically )
  - Draft
  - Category of the cargo

Due to its effective and useful technology AIS as an important tool for safety of navigation has expanded significantly since its introduction. The overload of the VHF



Data link due to the increased usage of AIS Systems is obvious. Therefore a more efficient and effective use of the radio spectrum is required in order to protect the AIS basic function for ship to ship collision avoidance.

Further main challenges for AIS information are security, availability and higher rate.

The AIS ship tracking system is unfortunately not without vulnerabilities (Balduzzi, Wilhoit, 2013).

Still it does provide a starting point to build upon for the implementation of services for the encryption of AIS information in the form of specifically formatted data as e.g. different predefined binary message formats.

The VHF Data Exchange System is a future maritime system with the main scope of creating new techniques for more effective and efficient use of radio spectrum, which will automatically protect the AIS main scope of collision avoidance. This system will improve the maritime communication applications, by offering them a robust digital transmission and much higher rate (up to 32x) than the current AIS. As stated in (ECC, 2013) and (IALA, 2014): "It is urgent necessary to allocate new frequencies for new and emerging applications of AIS technology in order to mitigate overloading of the AIS and VDES as the system to overcome this challenge should be optimized for data communication so that each VDES message is transmitted with a very high confidence of reception."

In *Activity 1: STM Tools and Operations* of the MONALISA 2.0 project this possibility is used to set up a route exchange format compliant with STM.

The ship to ship route exchange format defined in Activity 1 enables the exchange of planned short term routes between ships over the binary message 6 in AIS. However, this message with its chat function has a low priority in comparison to other messages which may be waiting to be sent out. This may cause problems in areas with high traffic density where message 6 may not be sent in time or at all.

Nevertheless, this approach can be considered to be a good basis for the STM compliant route exchange service. Due to the availability of AIS validation test for route exchange can be run very easy in the European Maritime Simulator Network (EMSN) or even in a real world scenario.

Based on this STM services can be extended to a core service called prioritisation service for communication channels. The AIS Message 6 can be one of the implementation possibilities to exchange short term routes between ships. Same information can be exchanged over other communication channels e.g. ECDIS. The prioritisation service of STM should be able to choose in dependence of the communication channel's load which of the channels at the given time can be used by the short term route exchange service. This service can be developed together with VDES (with the two parts of it the terrestrial and the satellite VDES), which as mentioned above will have a higher speed and a robust data exchange capability with potential for worldwide coverage. Maybe is VDES a more reliable technical infrastructure on which these kind of STM Services can rely on, than the actual AIS.



### 2.1.3 Satellite Communication

Unreliable and highly dependent on weather condition voice communication with ships via HF needs to be replaced by communication systems with higher bandwidth and reliable connectivity, which are the main STM requirements on the technical infrastructure.

Satellites can provide immediate and reliable communications using voice, telex or data channels. The operation continuity of a satellite communication network under conditions that sometimes render other methods of communication inoperable, is one of the main reasons for using satellite communication as technical infrastructure supporting STM. Nevertheless it is important to notice that (internet) access via sufficient communication link is a prerequisite or a boundary condition for STM Services.

Maritime VSat Technology with its cheap and small antennas is a very good basis for the technical infrastructure of STM. VSat antennas with diameters less than 2 m are cheap and can be installed everywhere. This makes it economic to use them in systems where a large number of terminals is needed, as in shipping. Nowadays VSat is using IP-based time division multiplexing that dynamically allocate bandwidth for each ship.

Generally the “network” bandwidth should be available when STM Services need it and the technical infrastructure should guarantee that the access point does not become a bottleneck. Dedicated bandwidth (SCPC) fulfils the discussed requirements of the STM Services, but on one hand it is too expensive as the client buys its own part of the satellite and on the other hand it makes a highly inefficient use of the bandwidth: We suppose that STM Services will not require the whole bandwidth all the time and the part of it being not used (idle) is wasted. Therefore it is more cost efficient to use shared bandwidth. Nowadays with IP-based time division multiple access technology bandwidth is dynamically allocated bandwidth to each ship for shared bandwidth. Oversubscription enables an efficient and cheap usage of the given bandwidth.

## 2.2 Information Security

In the maritime world, all information concerning navigational aspects of a voyage is safety critical. Additionally, many non-safety critical systems e.g. related to the transfer of paperwork, the identification of cargo or the storage of private data are critical for the smooth processing of maritime transports. Unfortunately, the European Network and Information Security Agency (ENISA) describes the awareness on information security challenges present in the maritime sector as “low to non-existent” (ENISA, 2011). Their report also states that this lack of awareness is not due to a lack of information security incidents, but rather due to the fact that in the maritime sector no mechanisms exist to identify or report these occurrences (ENISA, 2011).

In recent years, an increase in maritime traffic caused by globalized production and trade forces shipping personnel to navigate in increasingly crowded waters.



Unfortunately, despite great advances in available technologies, maritime stakeholders have failed to provide reliable equipment suitable to aid with and relieve masters from some of their administrative and navigational responsibilities. Some aids as e.g. AIS have been introduced, but these would be far more valuable if some security principles would have been considered during development in order to enable them to provide reliable information. Several examples show that AIS is not secure against spoofing attacks, i.e. authorities may be impersonated and false information inserted into the system easily as described by Trend Micro's security specialists (Balduzzi, Wilhoit 2013). According to researchers from the University of Texas, the same holds true for civilian GPS (Rutkin, 2013). These security flaws may cause serious security issues, time delays and identification issues which may be purposefully used to bypass regulations as for example reported by the Maritime Executive in 2012 (MarEx, 2012).

In general, many accidents could be prevented if assisting technology would provide a reliable picture of the current local situation. This data must not necessarily be encrypted, but the sender must be identifiable conclusively in order to prevent the insertion of false data. Additionally, stakeholders may be unwilling to share voyage information freely. In this case, encryption of the actual data becomes necessary as well. Therefore, encryption necessities must be considered for all future development projects.

It is very important therefore for the technical infrastructure as physical and logical enabler for STM Services to provide them with appropriate security. The technical infrastructure of STM can be attacked at many different levels as listed in (ENISA, 2011) e.g:

- Satellite communications
- Automatic tracking system
- Marine radar system
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Services using these systems can be attacked as well. The information security is not any more a problem of the land based systems. Shipping industry must incorporate proper defence in depth strategies to handle cyber threats(12).

### 3 Challenges

The greatest challenges faced by STM as well as the maritime world as it is today are connectivity and security concerns, sometimes an outdated technical infrastructure and the lack of collaboration between different systems.

The main needs and challenges of STM and its subconcepts regarding the technical infrastructure can be classified in the following categories:

1. Reliable connectivity
2. Open interface standards



3. Information security
4. Integration of the existing systems

As mentioned in the introduction, STM as a holistic approach to distribute service related to the berth-to-berth voyage enabling efficient, safe and environmentally sustainable sea transport, does not exist in this form today. Some of the STM services can be found in proprietary systems and therefore they do not take the full advantages of modern communication technique and information sharing principles. What STM aims to provide here are new tools making existing services faster, more secure always using up to date information based throughout the stakeholders.

Therefore, we will take into account the needs of STM services to be fulfilled by the technical infrastructure.

In order to maximize the advantages of using the route exchange service for the Dynamic Voyage Management (DVM) concept, a reliable connectivity and reliable information exchange is of high importance. The second and just as important requirement is that for a smart information exchange in bandwidth limited channels the interface standards need to be known. The existing technical systems can be boosted to reach this requirement by implementing a layered architecture as it exists for the internet (e.g. ISO-OSI layer model). In this case the open interface standards play a crucial role. The unique voyage identifier and its construction are a big step towards open standards and serve as an interface for the realization of other services e.g. route optimisation and validation.

Most of the services presented in the DVM concept deal with data that is sensitive for the shipping companies and needs to be protected. Therefore, the information security perspective has at least the same priority as the other requirements. The technical infrastructure cannot fulfill this need alone. In the future, information security must be guaranteed by the implementation of services even when those services are operating on preexisting technical systems. On the other hand, some of these technical systems can be classified as outdated ones, for which no security patches or support exists anymore. A decision must be made whether these systems should be replaced by newer ones or patched to new versions or architectures.

## 4 Conclusion

From the previous section it should be obvious that the coverage and availability of the existing technical systems does not cover a complete voyage. It is the main scope of the maritime service infrastructure framework to create a robust basis for enabling implementations that ensure that the right information arrives at the right time, to the right actor and in a secure way.

New communication technologies as VSat can immediately solve connection and bandwidth limitation challenges of today's VHF technology. One possibility would be to port the route exchange and further STM relevant information through VSat data exchange. VSat offers a higher bandwidth than normal VHF. This method is much



more stable than the one used to exchange information in VHF. Changing the channel from analogous to digital for exchanging the route will enable far more possibilities to track the information being exchanged not only through equipment available onboard but also through other devices as for examples smartphones or tablets.

Additionally, the use of open standard interfaces enables the introduction of a common infrastructure shared between old and new systems one step at a time. This system-independent approach will enable the gradual development of standards allowing for the efficient exchange of data.

One of those standards could include a function which allows switching between different communication channels in the communication layer, depending on their availability and the information being exchanged. In order to implement this type of channel scheduling the use of the correct data format as well as the correct connection of subscriber and publisher would be crucial. The user friendliness would depend on the technology being used to call the service. One user friendly interface option may be presented by tablets, since tablets present an established part of business and everyday life today.

In the future, all safety critical communication must be encrypted. Additionally, outdated technical infrastructure must be replaced appropriately in order to obtain an infrastructure capable of processing data in standardized open formats. The resulting open interfaces will allow competition between traditional and innovative service providers, hereby driving modernization.

Considering the diverse and often outdated technical equipment used in the maritime world today, the introduction of new standards and system's integrating all maritime operations presents a challenging task. Nevertheless, the advantages provided by STM in the areas of safety, efficiency and environmental impact are too significant to ignore.

One may regard the previously developed Aviation Transport Management system as a successful example of the opportunities provided by such a standardized system. Contrary to the world of aviation, in the maritime world many different systems are used heterogeneously. Therefore, the maritime world has the luxury to be able to adopt new systems step by step. This advantage should be exploited through the slow introduction of the new system's use as a requirement by strategically well located ports, which will eventually lead to the adoption of STM by all major maritime players.

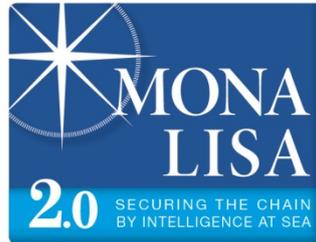
STM has the potential to tremendously improve communication in the maritime transport industry if used commonly. However, another challenge is presented by the necessity of its adoption by all major maritime stakeholders.



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