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1 Introduction

1.1 Background

Digitization has enabled numerous possibilities in diverse industries. An ever-increasing connectivity of people and things, together with Internet-based solutions, has brought information sources and information consumers closer. The amount of data being generated is enormous which has enabled many new service opportunities. More and more services on offer build upon continuous data streams and real-time data where service providers and consumers overrides the legacy of emergent information sharing structures.

The maritime sector has, however, not yet adopted the full potential of a connected digital society. In the distributed world of Maritime transportation, different actors have taken up digitization in the way that it serves them best. Typically, big actors have created systems for coordinating their transport operations. Maritime operations build upon the interplay between three types of core actors; shipping companies, ports, and cargo owners. This is an inseparable trinity that depend on each other for subsistence and rely on each respective actor’s ability to become efficient. Connected to this trinity are numerous coordinators (such as the shipping agent) and service providers (such as tug operators and pilotage), which enable efficient, safe and secure operations.

Over the past 13 years, shipping has been introduced to automated information exchanges through the adoption of an Automatic Identification System (AIS). One of AIS’ major purposes is to increase navigators’ situational awareness through the automatic exchange of key ship data, primarily supporting ship-to-ship identification and navigational situations according to the Convention on the International Regulations for Preventing Collisions at Sea, 1972, as amended (COLREG). AIS data is a tremendous improvement from the available and shared information in shipping and complemented the radar and other navigational tools.

However, the AIS’s broadcasting approach to share information has little or no distinction for privacy, security or data quality. As a communication channel AIS is, therefore, inappropriate for trusted networks of partners and authorities to share information for mutual benefit. Furthermore, AIS data as such lack details of a ship’s intended route and automatically and reliably updated estimated time of arrival, which results in a lack of shared situation awareness by maritime stakeholders.

Essentially, AIS voyage related data contains an ETA field for recording the next port of call, but it is a manually updated and with low information reliability. Practice has shown that this field, if used at all, is updated somewhere around leaving a port, and seldom changed until leaving the next port, regardless of events underway. In principle, this field could be automatically updated by some other on board system and become useful. But how will we know if it’s valid, automatically updated data or not? At least we need to supplement it with some kind of verification, which we can rely on.
The next problem is that the AIS leaves large ocean areas unmonitored all the time during a ship’s voyage as it operates within the VHF/FM range with a typical coverage of 20 to 30 nautical miles. Therefore, data need to be communicated in another way, using some other carrier than the AIS Static / Voyage data, through a controlled process.

Building on the AIS concept of communicating location and intentions, Sea Traffic Management (STM) has been introduced as a concept “encompassing all actors, actions, and services assisting maritime traffic from port to port”. Reports from the industry, *COWI (2013)*, indicate that the administrative burden is substantial for mariners, to a degree that is counter-productive and may even pose safety risks. By increasing the sharing of intentions and accomplishments to improve the common situational awareness among maritime stakeholders, there are a lot of potential gains.

STM will enable continuous communication about intentions among different maritime stakeholders. Examples of such intentions are to continuously communicate when approaching a port, plans for synchronization with terminal operators, when the port is ready to receive a particular ship at berth, desired routes the ship will take. STM covers a part of the multimodal logistics chain, encompassing sea as well as shore-based operations and includes concepts for Strategic and Dynamic Voyage Management, Flow Management, Port Collaborative Decision-Making (PortCDM).

1.1.1 The Sea Traffic Management Service Layers

Within STM, the notion of services is built upon a multi-layer framework as shown in Figure 1, where the role of digitization may play different roles without losing the human agency. The layered approach ensures that changes to one have no impact on the other layers. At the top of this framework operational services are performed by organizations/humans directed to different beneficiaries. These operational services may be supported by (digitized) application services that are offered via service platforms (*Lind et al. 2015a*). Application services build upon information/data services that are enabled by connecting service distributors and service consumers in a trustworthy and regulated way. Different communication services are used for enabling communication between different maritime stakeholders. Operational services may also, fully or partly, be digitized performing actions on behalf of the organizations it is a representative of.
2 The STM SeaSWIM Specification and Implementation

The implementation of the SeaSWIM specification, detailed in the layered model in Figure 1, is called the Maritime Service Infrastructure. The collection of all layers will provide the necessary support framework to support sharing of data, information and application services in a secure way.

Each layer has multiple services that make sure the implementation can be developed and iterated in a modular way. For example, the communications infrastructure components developed in the EfficienSea 2 project “Maritime Cloud” 1 could provide some Communications Services according to the SeaSWIM specification. However, as the industry evolves and alternative services emerge the current once could be replaced without affecting the rest of the current implemented Maritime Service Infrastructure.

2.1 Fundamental Objective and Principles

Developments within the maritime sector show trends towards increased connectivity (i.e. the IMO Common Maritime Data Structure that encompass all shipping and maritime domain aspects). For each particular voyage there is a large amount of data generated that could be used proactively for planning, realization,

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1 http://efficiensea2.org/
evaluation and reporting by different maritime actors. To enable service-based information sharing, an information-management concept is needed. Information management for the purpose of enabling STM specifically means that collection, management and distribution are performed collectively by different STM-actors according to the rules, registration and standards approved by different associations. The collection of requirements that enable the STM concepts has been coined SeaSWIM.

To support and enhance efficiency, security and sustainability throughout the maritime transport chain, Sea Traffic Management has been proposed to facilitate communication of intentions and accomplishment of actions prior to and during a sea voyage. The core principles behind the STM that SeaSWIM will support are that:

• A voyage is defined and all its attributes are bundled with a unique voyage identifier to allow communication about intentions “long” before the actual occurrence of the event, with a higher level of precision the closer in time to the actual occurrence. The basic strategy for the deployment of a Unique Voyage ID (UVID) is to set a standard for the composition of the UVID and then let each organization that utilises STM services use that particular voyage id.

• The intentions’ of sea and land based actors are provided to others well in advance and kept up to date as close to real-time as possible.

• Situational awareness is derived from multiple data sources.

• Digital data stores and data streams\(^2\) emanating from the various actors can be used for providing data to diverse systems used for different purposes.

• Recommendations of optimized routes are provided from authorised service providers. Secure information exchanges and authorized service realisation, discovery and distribution is realised through a service infrastructure governed by federations.

• SeaSWIM enables authentication of the identities of the two parties exchanging information. Almost all information is then transferred point-to-point between two actors, using industry wide standards as much as possible.

• All sensitive communication will adhere to strict state-of-the cyber-security standards.

• SeaSWIM recognize that data ownership and nominations rights belong to the party who is the source of the information.

SeaSWIM is inspired from the air traffic management concept of System Wide Information Management (SWIM) coined by Eurocontrol and FAA and used in the Single European Sky ATM Research (SESAR) project to implement a complete change in paradigm of how information is managed along its full lifecycle and across

\(^2\) Sequence of digitally encoded signals
the whole European ATM network. The following are the key principles for SWIM in ATM (SESAR Joint Undertaking 2011):

• **Separation of information provision / consumption.** Almost every participant is a producer as well as a consumer of information. It is not ideal to decide in advance who will need what information, obtained from whom and when. The key issue is to decouple producers of information from the possible consumers in such a way that the number and nature of the consumers can evolve through time.

• **Loose system coupling.** Where each of its components has, or makes use of, little or no knowledge of the definitions of other separate components. By doing this, the barriers between systems and applications are removed, and interfaces are compatible.

• **Using open standards.** An open standard is one that is publicly available and has various rights to use associated with it. It may also have various properties of how it was designed (e.g. open process). The terms "open" and "standard" have a wide range of meanings associated with their usage.

• **Using Service Oriented Architecture.** Driven by analysis of business processes and needs functionality is developed, packaged and implemented as a suite of interoperable services that can be used in a flexible way within multiple separate systems from several business domains.

The SeaSWIM specification for a Maritime Service Infrastructure Framework adheres to these same principles as SWIM for aviation. The principles allow governments and private actors to rely on the same service and information-sharing framework. However, the distributed nature of the maritime industry means that the different type of actor roles and rights is important to be acknowledged. Consequently, as an additional key principle, SeaSWIM also recognize that data ownership and nominations rights belong to the party who creates the data, as stated in the core STM principles. This further means that information management is distributed among the different actors and that data/information is stored at the different actors who allow access to beneficiaries to access the information.

2.2 Assumptions

SeaSWIM is a concept for system wide information management for the shipping industry that can be technologically implemented in different ways covering one or several communication channels. SeaSWIM does not regulate communication services, but rather builds upon existing standards. However the use of communication services has to align with the basic principles of SeaSWIM (e.g. not broadcasting information that is not desired to). SeaSWIM rather stipulate the premises of the interaction while the maritime stakeholders will handle the specific implementation. As previously stated, its definition has been inspired by the aviation industry, but reflects the legacy of the maritime domain in which competition exists among autonomous and rational agents that episodically connect. The SeaSWIM concept is an invitation to a wide range of actors to become part of a regulated and
federated data sharing and service-provisioning ecosystem. The SeaSWIM concept acknowledges the maritime industry as a complex adaptive system (Cashili and Medda 2012), with a large number of self-organizing autonomous agents where there exists variation in coupling (from loosely to episodic tight coupling). Central to SeaSWIM is to provide access to data streams (on the data/information service layer (see Figure 1 above). The SeaSWIM concept builds upon the assumptions that (Lind et al. 2014):

- Digital data streams can be open, proprietary, or hybrid. The intentions and performance of a ship-owner’s operations can represent the competitive edge of the company. Thus such data can be very sensitive and shared only when necessary for the profitable operation of the owner. The owner of a data stream must control access rights.

- There is a common standardized format for all information services in a common repository. An information service that is SeaSWIM-enabled (i.e. connected to SeaSWIM) must provide data according to a SeaSWIM specification, which adheres to industry defined data standards. The development of standards is evolutionary. Commonly the first service to use a new information element defines the standard, which may then be refined and evolve as others adopted it. The main driver for standard development is to minimize transaction and coupling costs for participating actors.

- There is a standardized information service interface to support interoperability. A data stream provider must provide it according to standardized definitions via a standardized SeaSWIM information service interface. A fairly comprehensive inventory of needed information services enabled by SeaSWIM should be exposed.

- The data and information service owner governs access to data. The provider of the data assigns and manages access rights for a specific use and distribution of the data and information services, such as the voyage to the requestor. Subsequently, there is a need for a repository of actors, which can be used by the data provider to assign access rights for the use of the data and information services (i.e., by whom it should be used and under which conditions). In the maritime decentralized model of access control, the data and information service owner handles validation.

- The existence of a data and information service is informed by a discoverability mechanism. SeaSWIM should contain mechanisms allowing a requester to learn about available data and information services and access procedures. This means that a SeaSWIM-enabled data stream should be requested to submit the existence of any data related to a certain voyage, ship etc. to this repository, but not the actual data. There is thus a need for a mechanism pointing at the existence of, and how a particular data stream can be found (e.g. data on a specific voyage, geographic area or port). The discovery mechanism should automate connectivity to the desired data stream.

- Provision: Data and information services are added as they come online and are added as technological development extends what can be sensed and measured.
The distributed data-sharing design that the SeaSWIM specification prescribes also gives room for new actors to enter the domain by providing new application or data and information services building on data made available by the various stakeholders. It should enable collaboration among stakeholders while preserving each stakeholder’s control of access to its data, support interoperability, as well as supporting the coordination of actions between single and multiple parties.

2.3 Core Functionality of the Maritime Service Infrastructure

To separate the conceptual specification of SeaSWIM from potential ways of implementing it this report refers to the Maritime Service Infrastructure when relating to the implementation. This Maritime Service Infrastructure framework for Sea Traffic Management is based on the characteristics of the maritime infrastructure framework proposed by Jensen et al. (2015a). In the definition of Sea Traffic Management concepts and services, the SeaSWIM specification extend this framework to include additional information management needs as the federated governance approach to service distribution and service discovery.

The table below summarizes key aspects of the SeaSWIM concept that is brought into the development of the maritime infrastructure framework.

Table 1: Key aspects of the SeaSWIM specification for a Maritime Service Infrastructure

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Characterization</th>
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<tr>
<td>Governance</td>
<td>• Federated structure setting standards, rules, and regulations, monitoring, and performs service portfolio management</td>
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<td></td>
<td>• Manages upkeep and development of the seaswim specification to account for changing needs over time</td>
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<tr>
<td>Functionality</td>
<td>• Identity management</td>
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<td></td>
<td>• Service management</td>
</tr>
<tr>
<td></td>
<td>• Message services (exchange of pre-determined types of information object (subscription, pull, receipts of received messages, service interaction patterns (e.g. Request-confirm))</td>
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<tr>
<td></td>
<td>• Life-cycle based service governance by issuer</td>
</tr>
<tr>
<td></td>
<td>• Service portfolio management to be performed by federation(s)</td>
</tr>
<tr>
<td></td>
<td>• Mechanisms for discoverability</td>
</tr>
<tr>
<td>Access control</td>
<td>• Determined by the data/information service provider (who, when, what)</td>
</tr>
<tr>
<td></td>
<td>• Regulation of terms of condition for use, time validity and potential counter actions</td>
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## Business model

- Market driven participation (competitive and imitative forces attract participation)
- Authority driven mandatory service interaction
- Depends on what data owners are willing to share (all or parts of a data stream)
- Financed by the beneficiaries and utilizers (incl. Authorities)

## Standardization

- Evolutionary standardization (proof of concept before standard)
- Standardized application services
- Standardized information services
- Standardized information service interfaces
- Common standardized format for different types of information exchanges
- Standardized and agreed definitions of used measures
- Standardized data and information objects
- Standardization for interoperability on different layers

## Technological implications

- Workable within and between diverse communication channels
- Platform independent on the different layers

## 2.3.1 Service Discoverability and Utilization

During MONALISA 2.0, the SeaSWIM concept has been defined for the purpose of enabling a technical infrastructure for service distribution and discoverability in such a way that access to different services are regulated by the information provider. This requires that functionality for identity and service portfolio management is enabled by the platforms providing access to STM services. Examples of identities are STM-actors, both as providers and consumers, (e.g. port operators, shipping operators), STM service providers, connected entities (e.g. ships), and other service providers. These identities provide access to services building on diverse information sources.

When a service consumer has discovered a service, contact can be established between service provider and service consumer, which involves agreement of the foundations for the service realization. Relationships between provider and consumer are in this way established.

By acknowledging the distributed characteristics of the maritime sector, the service interaction in the production and consumption of services will though be enabled by peer-to-peer interaction (1:1 or 1:m). This would then mean a need for integration between the different actors, such as the ship operator and the port of destination. Centralized service and identity registries enable the coupling.
Contemporary approaches advocate a service orientation and episodic tight coupling\(^3\) enabling interaction and collaboration among different stakeholders when desired. The implications of adopting this service-oriented approach to information sharing and data-stream access, services become the carriers of information. Services discovery is the mean for discovering information, for example a service enabling subscription to planned port approaches.

2.3.2 Federated Governance

It is important to raise some concerns about this increased degree of connectivity. Based on its legacy, the maritime industry is highly distributed, which is why it is important to facilitate the emergence of trustworthy, non-proprietary, data sharing environments. The willingness to share data with others in an industry, characterized by a high degree of autonomy and competition, requires that providers can trust that their data are utilized in accordance with their intentions and do not diminish their competitiveness.

Balancing between control and freedom is a crucial task in a world of rational, self-organizing autonomous agents. This autonomy in the maritime industry give rise to the need for governance structures that enable trust among service providers and service consumers but at the same time avoiding centralized control of resources, actions, and performances. As claimed above service provisioning and consumption needs to be allowed on a peer-to-peer basis. Consequently, governance needs to be realized by other means. A federative approach is preferred for this task. In fact, in different industries federated and regulated approaches for service interaction have become successful solutions for enabling exchanges between different actors (c.f. the SWIFT organization for secure bank transactions).

Means for governance in a federated approach are service portfolio management and monitoring. A federation is a “loose organization” consisting of representatives from multiple organizations where this constellation of organizational entities together creates the necessary trust for service providers and service consumers to take part in the service ecosystem. A service specific federation is an organization that creates the legal framework that regulates how services will be shared, realized, monitored, and evaluated between different actors (public and private). A federation is an organizational constellation that could exist in different forms, such as myfederation, i.e. the single organization as its own federation (as e.g. Apple), as industrial cluster, i.e. a network of (often) commercial actors agreeing about joint efforts and regulations (as e.g. flight alliances), and as regulating body, such as e.g. IMO. It is therefore likely that different federations serving its purpose will govern the maritime ecosystem. For some domains of application associations, such as IMO, IALA, and IMHA, would form or be part of the federation to preserve their interest. For some other domains of application nations will constitute the federation and in some case industrial alliances (as e.g. CIRM) would be the constituents of the federation. Of importance is that, each organizational constellation that make out the

\(^3\) Two entities that coordinate their actions for an event, either openly or undisclosed (Watson and Boudreau 2011).
federation needs to ensure trust by setting the rules and regulations for service distribution, discovery, and interaction.

Building on the maritime infrastructure framework as proposed by Jensen et al. (2015a), the service infrastructure framework for federated and distributed service interaction for STM is shown in Figure 2.

**Figure 2: Maritime service infrastructure for sea traffic management**

When services have been approved and services are being provided and consumed it is essential that the federation undertake a role in continuously ensuring that the services are being realized in accordance with the established specifications and rules. An approval of a service will have a period of validity for enabling renewed requirements on the service to be refined by the service provider. This means that the federation can use terms of provision and validity in its role of ensuring quality of the services in the portfolio and promoting service refinements. Figure 3 shows the role of the federation in the service lifecycle.
Figure 3: The role of the federation in the service lifecycle

Peer-to-peer service interaction will be impossible to monitor, but there are some other possibilities to monitor the realization of information services:

1. Information services are requested which means that the federation can get continuous reports on which, and how often, particular information services are requested for

2. If a potential Unique Voyage ID manager information service is introduced it would serve as a collector of the number of voyages being connected to the STM-network and information services using information about the specific voyage.

3. Reports on service realization built into the terms of approval could be channelized to the federation for evaluation

4. Reports from the community about the quality of services should be provided to the federation

2.4 Realization and Evolution

In order to enable the functionality of the SeaSWIM specification the key aspects (Table 1) will be implemented in a modular services oriented approach. Currently several systems and different technical implementations are capable of providing the basic characteristics of a SeaSWIM compliant system. Existing solutions for SeaSWIM will be evaluated in relation to the objective of providing a common platform for all maritime actors.

Beyond the conceptual realization model explained below during MONALISA 2 there has also been proof-of-concept implementations that give valuable insight into specific solutions and their functionality. First of all, the deliverable “MONALISA 2 - 1.6.2: Geoportal and SeaSWIM – services and tools” from Activity 1 showcase potential interfaces and applications for Voyage Management based on information sharing through an instance of SeaSWIM. Second, Appendix A includes an exemplary implementation of the SeaSWIM specification for a Maritime Service Infrastructure
based on the Maritime Cloud framework. In relation to the prototype in Activity 1, Appendix A focuses more specifically on communication and potential solutions to some of the main requirements in this layer.

2.4.1 SeaSWIM – A General and Adaptable Framework

The SeaSWIM specified Maritime Service Infrastructure will be an enabler for a highly regulated (command and control) approach as well as a market driven approach, both in terms of service deployment and in terms of making business deals. The latter will enable the invitation of new services and actors to an open market. The service registry will allow standardized as well as proprietary or regional services to coexist. In this respect, the organization(s) governing the implementation of SeaSWIM will need to fill the continuum from highly regulated to market driven, as well as from proprietary to standardized solutions, see Figure 4.

![Figure 4: Filling the continuum requires commitment by stakeholders](image)

2.4.2 Governance Evolution

One of the primary purposes of the Maritime Service Infrastructure framework will be to enable secure exchange of information between trusted parties. Thus, vetting of identities by relevant federations or authorities will play a significant role in building a ‘Chain of trust’.

To provide a governance structure that encompass the multitude of stakeholders of the maritime sector, a federative approach is proposed where stakeholders who wish to expand the capabilities of the SeaSWIM instance meet their specific needs.
Furthermore, to meet the needs of the maritime business in the long term, it will need to evolve with the business and societal demands as well as technological developments. This calls for evolutionary processes within the governing community:

5. Organizational evolution – the composition of the Governing Board and the business model behind operation of the infrastructure services needs to evolve, to reflect the trends in the maritime business and societal demands.

6. Technical information services exposed via the Maritime Service Infrastructure will evolve over time. Based on lessons learned from introduction of ECDIS and AIS, it is foreseen that a structured evolutionary process for testing and harmonization of information services leading to standardization, rather than standardization by committee before implementation, will support better quality software and improved usability.

Several domains or federations of interested parties could have a stake in the Maritime Service Infrastructure concept, which expands the scope beyond e-navigation. This calls for a multi-tenancy approach, whereby relevant stakeholders can cooperate on governing the operation and evolution. Inspiration could be found in the World Wide Web Consortium (W3C)\(^4\) governing standards for the internet, or the Eclipse Foundation\(^5\), gathering stakeholders on projects within the Automotive industry.

Another example is the Open Geospatial Consortium (OGC). The OGC is an international consortium of more than 475 companies, government agencies, research organizations, and universities participating to develop publicly available geospatial standards. OGC Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. OGC Standards empower technology developers to make geospatial information and services accessible and useful with any application that needs to be geospatially enabled\(^6\).

In all of these examples, stakeholders who wish to influence the direction of evolution to support any given interest, will have to commit resources to the community to achieve influence on the governing board. If for instance the IMO decides to recommend Flag States perform vetting of ships identities in the registry, an operational resource has been committed, which could secure the IMO a seat in the governing board. If organizations such as IALA or CIRM decide to commit resources for supporting technical harmonization and standardization within the community, it could allow them a seat on the board.

Figure 5 shows the proposed governance model. It is a layered model in which room is given to one or several federations to semi-control the deployment and realization.

\(^4\) www.w3.org/Consortium/
\(^5\) https://eclipse.org/home/index.php
\(^6\) http://www.opengeospatial.org/contact
of services between maritime stakeholders. The framework acknowledges that most interactions among maritime stakeholders will occur on a peer-to-peer basis. A federation(s) needs to create an instance of SeaSWIM that is trusted by maritime stakeholders using the framework as a common service provisioning infrastructure.

![Diagram](image)

**Figure 5:** Proposed federated approach to a foundation governing the evolution and operation of a maritime services infrastructure framework

### 2.4.3 Service Portfolio Evolution

Sea Traffic Management covers multiple service domains, such as weather services, port services, navigational services, and more generic service infrastructure services etc. This requires the involvement of multiple federations where each of these has to be constituted by trustworthy organizational bodies. For example, it is natural that IALA is represented as part of the federation for navigational services. Service portfolio management includes:

- Setting the rules for which standards to meet for approved services
- Coming to agreements about measures, rules and protocols to be used
- Ensure that infrastructure services of Sea Traffic Management meet enough quality
• Collect judgements and reports from the use of services as a basis for opportunity identification, refinement and exclusion of services

The different services listed in the service portfolio would have different status; proposed vs. approved. A proposed service can consequently be rejected and not taken up in the service portfolio. The services should however be seen as offers on an open market. Some services might be restricted to particular geographic zones, as e.g. only applicable for a particular port. The service ecosystem will thus allow for different kinds of services as well as the same kind of services issued by different service providers.

From an industry perspective, a cluster of industry partners (i.e. container shipping or offshore operations) might wish that the infrastructure supports its special interests – for example sharing of data on simultaneous operations in a confined area. This network would then need to commit development or operational resources to get a seat in the governing board, securing those interests by evolving the operation and infrastructure services in their direction. In return, the community may focus the development efforts on supporting the needs of the industry cluster in question. In developing and deploying its information services, while benefitting from the existing Infrastructure for service portfolio management, as well as identity and key management to support access control and billing, Figure 6.
2.4.4 Evolution of Standards

Standards play an essential role in this world of distributed service offerings. For example, in the efforts of defining STM it has been essential to standardize a route exchange format to be included in the ECDIS performance standard. The ongoing revision of the test standard for ECDIS, IEC 61174, which is expected to be published as edition 4 by the end of 2015, has provided an opportunity for introducing a standardized route exchange format. In parallel, the revised IMO Performance Standards for ECDIS shall also have to be amended. The MONALISA 2.0 project has taken the opportunity of the establishment of the European Maritime Simulator Network to implement and test the suitability of this standardized exchange format for exchange of voyage plans and related information, in support of the development of STM concepts. Results from these simulations would be used to support and validate the STM concepts.

However, care need to be taken to avoid coming into time-consuming and detailed standardization processes as e.g. making universal information reference models. A potential alternative for the service ecosystem of Sea Traffic Management relies on the principle of evolutionary standardization. This principle means that if a certain protocol and/or measure is being used that has not earlier been used, this first

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Resolution MSC.232(82)
version, after proof of concept, will set the standard. This standard will then last until an argumentative base has been provided for refining this standard. Such an approach combined with that an exponential growth of available services is expected to facilitate many service opportunities. The role for the federation in performing service portfolio management thereby becomes crucial.

3 SeaSWIM Service descriptions

The emergence of Sea Traffic Management builds upon possibilities for exponential growth of available services. Anyone should be allowed to search for approval of a particular STM-service to be offered (compare to smart-phone app stores). Approved services will have a “quality-mark” as an STM-service as way to show consumers that the service meets the required standards. Such standards are both of generic characteristics, such as the service being specified in accordance to the service specification language, as well as domain specific characteristics, such as being compliant with established rules and set of emergent standards. Due to that most service interaction will be realized on peer-to-peer basis, standards for publish-subscribe services would be necessary to provide for the realization of such services.

3.1 Identity Management

Objective:
To manage an identity registry of maritime stakeholders providing access to, and consuming, services.

Description:
This service provide identification to maritime stakeholders to be used for secure authentication and verification. This is done by keeping a register of identities and manage the definition of roles. Such a service is necessary to support access control and secure service interaction to achieve a chain of trust.

Service provider:
Platform providers related to a layer for a certain area of operation

Area of operation:
Information sharing and service interaction in different domains of maritime activity is using the same framework. For STM, SeaSWIM is an enabler for the realization of Sea Traffic Management Services.

Using:
• Governance and monitoring (O-service)
• Authentication (I-service)
3.2 General Service Portfolio Management

**Objective:**
A lifecycle approach to the facilitation of the development, publishing, maintenance, use and liquidation of operational services necessary for the functionality of SeaSWIM

**Description:**
This service enables Quality assurance of proposed services and provides a quality stamp to the service (STM qualified) by principles of auditing

**Service provider:**
Related federations for their domain specific task with adjacent processes for service development, provision, refinement, maintenance, use, and liquidation.

**Area of operation:**
Information sharing and service interaction in different domains of maritime activity is using the same framework. For STM, SeaSWIM is an enabler for the realization of Sea Traffic Management Services.

**Using:**
- Governance and monitoring (O-service)

3.3 Access Management

**Objective:**
To provide functionality to access services (and information sources) based on the desires of the service provider to enable trusted information exchanges.

**Description:**
Provides basis for access control by enabling the information source (by providing a service based access to information/data) to decide upon which actors in the identity registry that could access the service. The access control could be related to dimensions of time, geospatial, and its use in different types of applications. This service would enable actors to push out information and to sign up to subscription services

**Service provider:**
Platform providers related to a layer for a certain area of operation

**Area of operation:**
Information sharing and service interaction in different domains of maritime activity is using the same framework. For STM, SeaSWIM is an enabler for the realization of Sea Traffic Management Services.

**Using:**
- Identity Management (O-service)
- Service Portfolio Management (O-service)
3.4 Governance and Monitoring

Objective:
To quality assure, govern, and monitor the service ecosystem of a particular domain in accordance with the rules and regulations set by and for the federation.

Description:
• Monitors the performance of the service eco system
• Governs the development community by establishing technical and operational guidelines, standards, and protocols that must be acknowledged in service provision and discovery.
• Maintain a service specification language for the purpose of enabling service providers and consumers to interact

Service provider:
Related federations for their domain specific task creating conditions for the performance of the service ecosystem

Area of operation:
Information sharing and service interaction in different domains of maritime activity is using the same framework. For STM, SeaSWIM is an enabler for the realization of Sea Traffic Management Services.

Using:
• Service portfolio management (O-service)
• Identity management (O-service)

4 Discussion

A common maritime communication and service infrastructure, SeaSWIM, is key for enabling innovation in the maritime sector. In order to establish a substantially used service-provisioning infrastructure a key challenge is to enable that this “backbone” of communication is used for different purposes. This means that there will be a need to join forces with several on-going initiatives that rely on enhanced communication between different maritime stakeholders. SeaSWIM does not have the aim to just be directed towards the provision of, and the discoverability, of STM-related services. This maritime communication and service infrastructure has been designed to suit different purposes but still relying on the assumption of that each maritime actor needs to be able to act in accordance with Mare Liberum 1609 (Freedom of the seas). Due to this legacy it is highly essential that the characteristics of the underlying framework for an information sharing and service distribution rely on a foundation that allows “non-governed” peer-to-peer interaction. The parties engaged in such peer-to-peer interaction need to be able to rely on the fact that the information being shared is just being shared with the ones that are intended recipients of the information. Building trust is a key issue to overcome company specific solutions.

5 Conclusions

A common Maritime Service Infrastructure framework, based on the SeaSWIM specification, supporting authorization, validation and secure information transfer, as well as management, publication and discovery of standardized information services will benefit a large number of maritime stakeholders within different areas of application, Figure 7. This is a call to harmonize contemporary efforts and join forces.
for a common framework to be applied in different settings and stimulate information sharing and service distribution among maritime stakeholders. The definition of a joint framework is the beginning of a journey towards a sustainable digital infrastructure for the maritime transport domain.

Figure 7: The digital infrastructure framework at the intersection of maritime activity

6 References

Appendix A – Maritime Cloud Communication Services for the SeaSWIM Specification

This appendix describes the Maritime Cloud solution for e-navigation, Jensen et al. (2015b), as one possible realization of parts of the SeaSWIM specification related to the communication infrastructure.

Background

The principles of information sharing and service distribution rely on a (generic) maritime service infrastructure specification; SeaSWIM. In order to be compliant with contemporary initiative this generic maritime infrastructure framework is applied to Sea Traffic Management. The generic framework specification and its application of the framework for Sea Traffic Management, is detailed in this section.

Contemporary developments within the maritime sector show trends towards increased connectivity. Streams of (near) real-time data support decreasing uncertainties and increased levels of quality assurance in maritime operations. Cooperating business clusters, large-scale ship operators and ICT and telecom providers are developing service infrastructures – ‘clouds’ and platform solutions.

However, a common, secure and interoperable framework for service publication, discovery, provision and use, where existing and new actors can participate on equal terms, would benefit not only the vision behind the e-navigation strategy, but also numerous other initiatives.

Implementation

By using a specific solution a certain set of SeaSWIM requirements would be met. In the case of the Maritime Cloud (Fig. 8) the following characteristics would be inherited:

- Management of Identities - shore based as well as ship borne
- Mechanisms supporting authorization, validation and secure information transfer
- Management, publication and discovery of standardized information services
- Maintaining interoperability while separating an information service from a specific communication channel (enabling utilization of evolving communication technologies)
- Enabling communication targeted a geographic context
The Maritime Cloud provides functionality for identity and service registry for the data layer. The service registry enables service providers to expose STM services and service consumers to discover STM services. Sea Traffic Management is defined by its services where the services are exposed by service providers for discovery by service consumers in the service registry. The service provider uses the identity registry as a basis to specify which actor or role that should have access to a certain service. When applicable, keys are issued and used for granting and getting access to the service. Access to real-time data streams would be given by a certain identity via a service listed in the service registry given that the service consumer has the right access key.

**Identity management – the Maritime Identity Registry**

Providing an identification key like ships IMO number or MMSI number used for identification offer a limited level of confidence in with whom data are being exchanged. These identifying keys are not universal to all maritime stakeholders, or can be used by them for secure authentication in a digital conversation. In order to support access control and secure exchange of information, a uniform identity concept is needed, whereby different types of identities can be vetted by relevant federations or authorities to achieve a ‘chain of trust’, combined with secure mechanisms supporting verification of authenticity and integrity, as well as confidentiality.

**Service portfolio management – The Maritime Service Portfolio Registry**

A Service Registry contains provisioned service instances as defined by service specifications, Fig. 9, and will enable service providers, consumers, and regulatory authorities to share a marketplace for services. The service registry does not provide maritime information itself, but a specification of services and the information they carry, plus the technical interface to obtain it. The service registry enables the “provider” to “publish” its service instances so that “consumers” are able to “discover” them and obtain interface information required to use a service. Some services are mandatory founded in the requirements put forward by regulating authorities while other services are consumed on a more voluntary basis. However
most times highly necessary for achieving a successful plan (such as e.g. weather routing) and a safe journey (such as e.g. shore-based monitoring).

A ‘service’ may in principle span from non-digital operational services (e.g. specifying a VHF working channel or phone number of a VTS, and describing services provided) to a technical machine-to-machine digital interface definition of a service enabling automated transfer of information in an automated Ship Reporting System using standardized data structures. Services may span public, standardized instances to proprietary. While some services are public, the mechanisms provided by the Maritime Identity Registry for identity and key management enable providers of information services to perform access control, thus enabling management of rights for access. This allows information owners to decide whom they share information with, based on validation on specific approved identities, or role based rights of access.

**Maritime Messaging Service**

The Maritime Messaging Service is a carrier agnostic messaging hub, designed to allow seamless roaming, enabling global interoperable connectivity across varying data links with varying technical characteristics and limited bandwidth. The Maritime Messaging Service is not intended to carry all maritime communication, but to provide an enabler for roaming or authentication of identity in a digital conversation, possibly using another protocol. The Maritime Messaging Service will enable a geo-aware protocol for ‘geocasting’ – a ‘logical broadcast’ with a coverage area, where other actors can ‘listen’ (subscribe).

**The ALMANAC**

A downloadable digital publication called ‘the ALMANAC’ will contain registered Identities, published contact information and service instances, plus public keys for encryption. This provides ships with a varying availability of communication links access to ‘white pages/yellow pages’ functions like identity and service discovery for initiation of secure peer-to-peer communication between registered parties without requiring online access to the central registries.

**Interaction Layers**

Inspired by the Open System Interconnection (OSI) model, the world of Digitization that the Maritime Infra-structure Framework address, can be positioned in different abstraction layers. In this section the Maritime Cloud and SeaSWIM concepts are introduced, and we consider how they fit as components of a common maritime-infrastructure framework.
Looking at the common maritime infrastructure from the outside, there would be app stores for different domain specific information services and consequently be the portal to the maritime-infrastructure framework. Such app stores will provide access to applications, as stand-alone devices (such as e.g. e-navigation approved devices) as well as stand-alone application using other types of devices. The ‘App store for STM’ will be the SeaSWIM portal to Applications approved for interaction through STM data services. Consequently, the Maritime Infrastructure Framework mainly concerns a data/information service layer, and an application layer, but connected to a communication layer, Fig. 10. The communication service layer expresses communication as a service in which different communication techniques are identified. The data/information service layer (data/information as a service) provides access to diverse data/information sources (data streams or data stores) by standardized interfaces (such as APIs). On this layer access to data streams are provided further processed to create information. Typically, the data/information services registered in the service registry as empowered in Maritime cloud are used to provide access to data/information to be used in different applications. The application layer thus uses available data/information services in the creation of new front-end application and/or in the expansion of functionality in existing applications (as e.g. in administrative systems and/or navigational equipment). Access control, i.e. who can access which services under which conditions, is to be managed on the different levels and could be constrained by dimensions of time, geographical
location, and/or which application that accesses the data/information service layer combined with the user of that application. The governance and monitoring of the emergence of the information services needs is according to the Maritime Infrastructure Framework proposed to be performed as a federated approach – more or less regulated, which is similar to the approach described in the main SeaSWIM description.
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