

Service and Communication Infrastructure for Sea Traffic Management

Mikael Lind, Viktoria Swedish ICT, Sweden, mikael.lind@viktoria.se

Jens K. Jensen, Danish Maritime Authority, Denmark, jkj@dma.dk

Sandra Haraldson, Viktoria Swedish ICT, Sweden, sandra.haraldson@viktoria.se

Richard T. Watson, University of Georgia, Athens/USA, rwatson@terry.uga.edu

Per Setterberg, Swedish Maritime Administration, Sweden, Per.Setterberg@sjofartsverket.se

Per-Erik Holmberg, Viktoria Swedish ICT, Sweden, Per-Erik.Holmberg@viktoria.se

Abstract

The introduction of Sea Traffic Management services relies on infrastructures that enable trustworthy information sharing and service provisioning/consumption processes. For this purpose, a federated and regulated approach to information sharing and service distribution is proposed. Such an approach would position the governance of different services in the continuum of hierarchical (i.e. command and control) to market-driven approaches. In this paper the maritime infrastructure framework is presented and applied to Sea Traffic Management. The full potential and large-scale implementation would come when the same framework is applied in different areas of application that rely on information sharing, service interaction, and (digitized) actor collaboration.

1. Introduction

Digitization has enabled numerous possibilities in diverse industries. An ever-increased connectivity of people and things, together with Internet-based solutions, has enabled possibilities to decrease the distance between information sources and information consumers. The amount of data being generated is enormous which has enabled many new service opportunities. More and more services being distributed 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 used the full potential of a connected digital society. Over the past 10 years, parts of shipping have been introduced to automated information exchanges through the adoption of AIS. One of AIS' major purposes is to increase navigators' situational awareness through the automatic exchange of key ship data, primarily supporting peer-to-peer identification and navigational awareness in COLREG (International Regulations for Preventing Collisions at Sea 1972) situations. AIS is however not enough for gaining desired safety, efficiency, and sustainability effects. AIS data as such and existing mechanisms for sharing it, are not sufficiently secure and do not provide detail on a ship's intended route or 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 we cannot be sure we have AIS coverage all the time during a ship's voyage. Therefore, data need to be communicated in another way, such as using some other carrier than the AIS Static / Voyage data, through a controlled process.

Building on the AIS concept of communicating intentions and reached states, Sea Traffic Management has been introduced as a concept "encompassing all actors, actions, and services assisting maritime traffic from port to port. STM is a part of the multimodal logistics chain, encompassing sea as well as shore based operations. The STM concept includes concepts for strategic and dynamic voyage management, flow management, port collaborative decision-making, and the service based communication infrastructure concept SeaSWIM. STM puts an emphasis on interopera-

ble and harmonized systems allowing a ship to operate in a safe and efficient manner from port to port with a minimal impact on the environment” (as defined by the MONALISA 2.0 project).

The need for STM comes from the opportunity for increased efficiency in the maritime business, i.e. the movement of goods (and passengers) on sea. There is a potential to reduce shipping’s environmental footprint by increased coordination supported by digitalization. Sea Traffic Management is concerned with the need to increase the efficiency in operations within and between ports. This could be enabled by maximizing the utilization of a port’s facilities and minimizing the use of energy to steam between two ports, constrained by safety considerations. Necessary for enabling these goals is increased digital data sharing. There is a need for a concomitant directory of the information services based on these shared digital data streams. Such a directory would support distribution, discoverability, and realization of information services.

STM would thus 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 take a particular vessel at berth, desired routes the vessel will take etc. There is thus a lot of data generated related to a particular voyage that could be used proactively for planning, realization, evaluation and reporting by different maritime actors. 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 enlarging sharing of intentions and accomplishments for an increased common situational awareness among maritime stakeholders, there are apparently a lot of potential gains.

It is, however, 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. The value of aggregated information based on the combination of other sources of information, such as enhanced situational awareness, must exceed the cost of data sharing. In different industries federated and regulated approaches for service interaction has gained a lot of interest (c.f. the SWIFT organization for secure bank transactions).

Contemporary approaches advocate a service orientation and episodic tight coupling enabling interaction and collaboration among different stakeholders when desired. In this short paper a maritime service and communication infrastructure framework for Sea Traffic Management is introduced. This is based on the maritime infrastructure framework proposed by *Jensen et al. (2015a)*. In the definition of Sea Traffic Management concepts and services, SeaSWIM has been used to define the necessary needs for a federated approach to service distribution and service discovery. The Maritime Cloud solution for e-navigation, *Jensen et al. (2015b)*, as a global service distribution platform has been identified as one possible realization of SeaSWIM.

In the following section, the characteristics of Sea Traffic Management are outlined. Introducing the (generic) maritime infrastructure framework follows this. Then, this generic maritime infrastructure framework is applied to Sea Traffic Management proposing a service and communication infrastructure framework for Sea Traffic Management. This application, the maritime service and communication infrastructure framework for Sea Traffic Management, is then further detailed. The paper is concluded with some final reflections.

2. The characteristics of Sea Traffic Management

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. They do however rely on other actors’ ability to become efficient. To overcome this situation, Sea Traffic Management has been proposed in which intentions of upcoming, and the

accomplishment of, actions are communicated prior to and during a sea voyage. STM puts an emphasis on interoperable and harmonized systems allowing a ship to operate in a safe and efficient manner while also lowering its carbon footprint.

Maritime operations build upon the interplay between three types of core actors; shipping companies, ports, and cargo owners. This is an inseparable trinity meaning that neither of them exists without the other. Connected to this trinity there are numerous coordinators (such as the shipping agent) and service providers (such as tug operators) enabling efficient operations. The basic logic behind STM builds upon a few core principles:

- a voyage is defined and all its attributes are bundled with a unique voyage identifier.
- 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 streams 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.

The sub-concepts of Sea Traffic Management and some core services are:

- Strategic Voyage Management which has the purpose of optimising a company's initial planning phase for a voyage by enabling an up-to-date awareness of all influencing factors relating to the undertaking and success of the voyage being planned. The planning horizon can be years, months, weeks, or only hours. Examples of core services are voyage_id manager, fleet management, and route optimization.
- Dynamic Voyage Management with the purpose of providing ship operators with an up to date and dynamic flow of information to improve the efficiency and safety in the maritime industry, and reduce its environmental impact. Examples of core services are route optimization and route validation.
- Flow Management with the purpose of optimising and increasing the safety of the sea traffic flow during all planning and executing phases based on a situational awareness founded in multiple instances of sea voyages. Examples of core services are enhanced monitoring and traffic coordination.
- Port Collaborative Decision Making (Port CDM) with the purpose of supporting just-in-time operations within ports and in relation to other actors being coordinated by the efficient and collaborative port. Based on an enhanced common situational an increased ability to predict state changes will enable this. Examples of core services are Port Call Synchronization, Port Call Optimization, and Port Call Monitoring.

The infrastructural realization of these four sub-concepts is enabled by a fifth concept; a Sea System Wide Information Management (SeaSWIM), facilitating sharing of data in a common service provision and consumption environment and structure. SeaSWIM has the purpose of enabling service interaction for different purposes. This paper is to be seen as a specialization of SeaSWIM for Sea Traffic Management purposes. Information management for the purpose of enabling Sea Traffic Management is conceived "as the collection and management of information from one or more sources and the distribution of that information to one or more audiences", Wikipedia Information Management. Specifically this means that collection, management and distribution are performed collectively by different STM-actors according to the rules, registration and standards approved by the federation. The sub-concepts are defined by their services, which could be of different characteristics; core and add-on services with the characteristic of being back-end, operational and/or analytical/supportive services.

3. The components of the Maritime Infrastructure Framework

3.1 The foundation of the Maritime Infrastructure Framework

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. Inspired by the OSI-model, http://en.wikipedia.org/wiki/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.

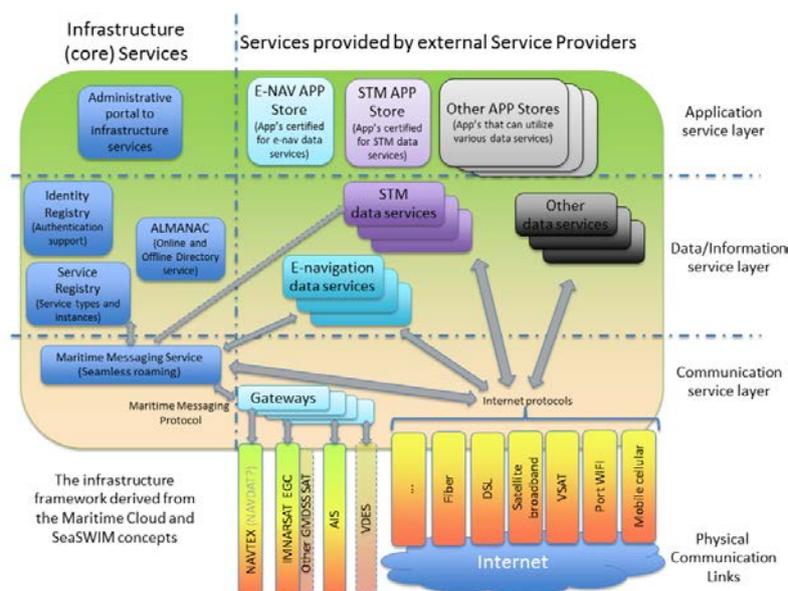


Fig. 1: Conceiving digital infrastructure in the maritime sector by a layered model

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 Cloud’. 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. 1. 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 (see section 3.3 below).

3.1.1 The SeaSWIM concept and its characteristics

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. 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 Fig. 1 above). The SeaSWIM concept allows distribution of, and access, to data streams 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 data streams in a common repository. A data stream that is SeaSWIM-enabled (i.e. connected to SeaSWIM) must provide data according to a (SeaSWIM) defined data standard. The development of standards is evolutionary where the first service to use an information element defines the standard, which may then be refined and evolve as it is adopted by others. The main driver for standard development is to minimize transaction and coupling costs for participating actors.
- There is a standardized API for accessing data streams to support interoperability. A data stream provider must provide a stream according to standardized definitions via a standardized SeaSWIM API. A fairly comprehensive inventory of needed data services enabled by SWIM should be exposed.
- Access to data is governed by the data stream owner. The provider of the data assigns and manages access rights for a specific use of the data distributed in data streams, 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 (i.e., by whom it should be used and under which conditions). In a decentralized model of access control, the data stream owner handles validation.
- The existence of a data stream is informed by a discoverability mechanism. SeaSWIM should contain mechanisms allowing a requester to learn about available data streams 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, vessel 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 streams are added as they come online and are added as technological change extends what can be sensed and measured.

Such a distributed data sharing design also gives room for new actors to enter the domain by providing new 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.

The SeaSWIM concept builds upon a governance structure in which federations on relevant parties create rules for and monitor the information exchange and service provision and discovery performed among the maritime stakeholders. The table below summarizes key aspects of the SeaSWIM concept that is brought into the development of the maritime infrastructure framework.

Aspect	Characterization
Governance	<ul style="list-style-type: none"> Federated structure setting standards, rules, and regulations, monitoring, and performs service portfolio management
Functionality	<ul style="list-style-type: none"> Identity management Service management Message services (exchange of pre-determined types of information object (subscription, pull, receipts of received messages, service interaction patterns (e.g. request-confirm)) Life-cycle based service governance by issuer Service portfolio management to be performed by federation(s) Mechanisms for discoverability
Access control	<ul style="list-style-type: none"> Determined by the data/service provider (who, when, what) Regulation of terms of condition for use, time validity and potential counter actions
Business model	<ul style="list-style-type: none"> Market driven participation (competitive and imitative forces attract participation) 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	<ul style="list-style-type: none"> Evolutionary standardization (Proof of concept before standard) Common standardized format for different types of information exchanges Standardized and agreed definitions of used measures Standardized API for access to data streams / data / information objects Standardization for interoperability on different layers
Technological implications	<ul style="list-style-type: none"> Workable within and between diverse communication channels Platform independent on the different layers

3.1.2 The Maritime Cloud concept and its characteristics

Common to the findings of several e-navigation test bed projects, the need for an infrastructure supporting the following enabling elements have been identified, Fig. 2:

- 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

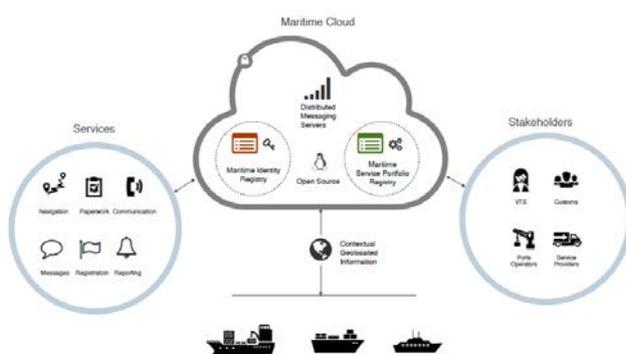


Fig. 2: Core elements of the maritime cloud

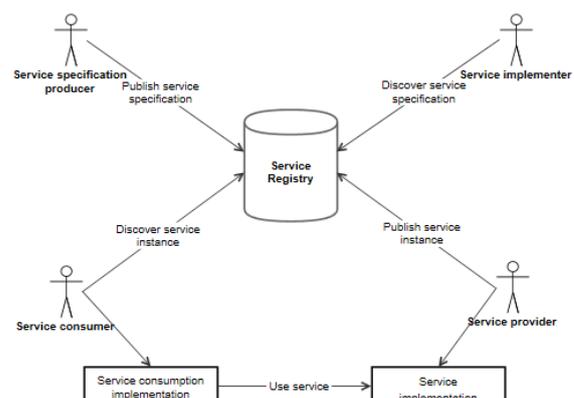


Fig. 3: Enablers for service development

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 by themselves be used 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. 3, 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.

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 (MMS)

The MMS 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 MMS 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 MMS 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.

3.3 The maritime infrastructure Framework

3.3.1 Governance of the common maritime infrastructure framework

The 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, as described in section 3.2 above, will allow standardized as well as proprietary or regional services to coexist. In this respect, the organization(s) governing the infrastructure framework will need to fill the continuum from highly regulated to market driven, as well as from proprietary to standardized solutions, Fig. 4.

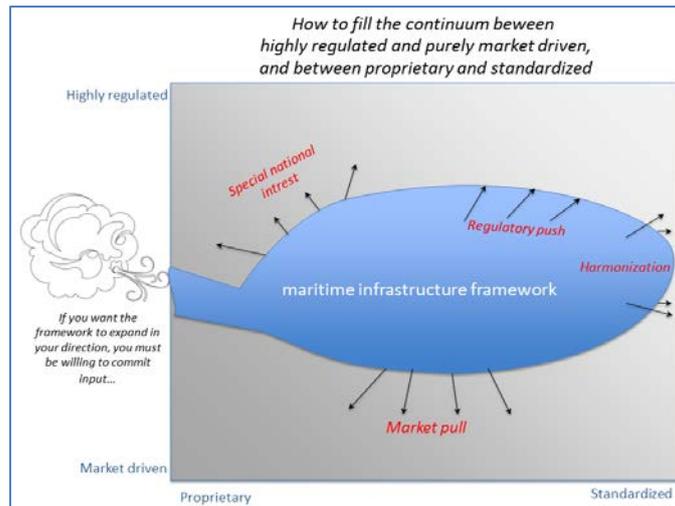


Fig. 4: Filling the continuum requires commitment by stakeholders

In achieving this, we proposed a governance structure, which allows federations of stakeholders who wish to expand the capabilities of the infrastructure to meet their specific needs, to achieve influence on the evolution of the infrastructure, by committing resources to its evolution and operation.

3.3.2 A Governing Foundation or Consortium

Several domains or federations of interested parties could have a stake in the 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) - www.w3.org/Consortium/ governing standards for the internet, or the Eclipse Foundation (<https://eclipse.org/home/index.php>), gathering stakeholders on projects within the Automotive industry, as well as ‘the Internet of Things’.

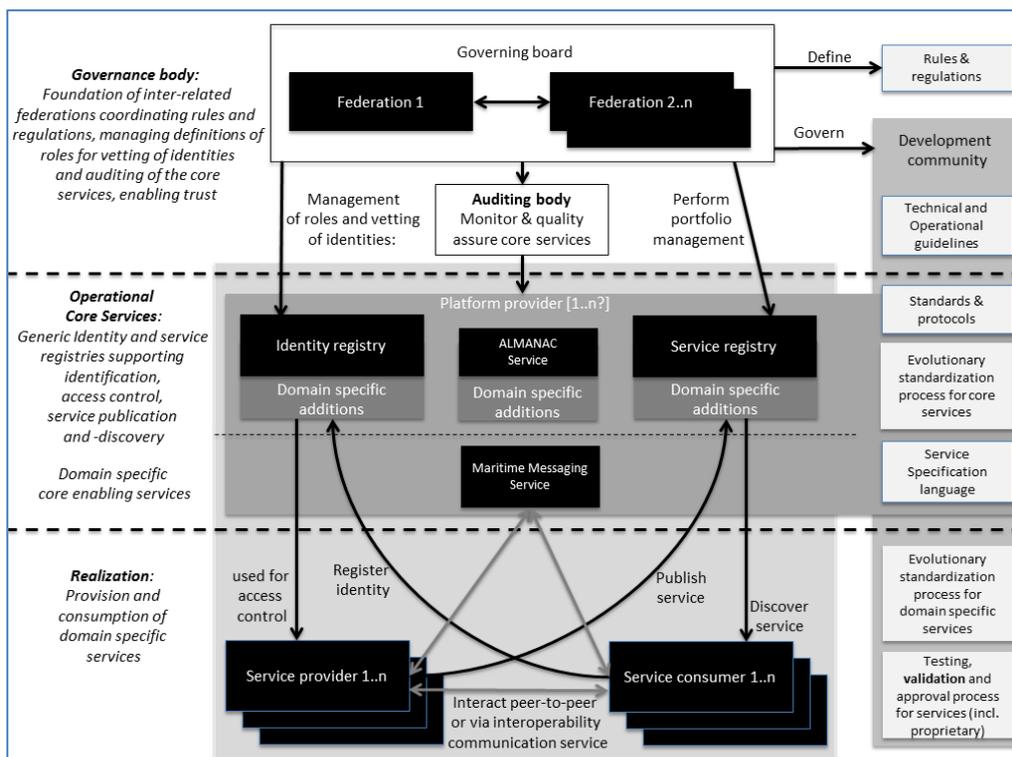


Fig. 5: Proposed federated approach to a foundation governing the evolution and operation of a maritime infrastructure framework

In both 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. Fig. 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 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 infrastructure trusted by maritime stakeholders using the framework as a common service provisioning infrastructure.

One of the primary purposes of the 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'. The interests of federations willing to commit operational resources that benefit the community should be represented in 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 buy them a seat on the board.

3.3.3 Evolutionary processes within the community

If the Service Infrastructure is 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:

1. Organizational evolution – the composition of the Governing Board and the business model behind operation of the core services needs to evolve, to reflect the trends in the maritime business and societal demands.
2. Technical Services exposed via the 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 services leading to standardization, rather than standardization by committee before implementation, will support better quality software and improved usability

3.3.4 How market demands may evolve the Service Infrastructure

A significant cluster of industry partners, say within container shipping or offshore operations, might wish the Infrastructure to support its special interests – say sharing of data on simultaneous operations in a confined area. It would need to commit development or operational resources to get a seat in the governing board, securing those interests by evolving the operation and core 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 services, while benefitting from the existing Infrastructure for service portfolio management, as well as identity and key management to support access control and billing, Fig. 6.

A common maritime infrastructure framework supporting authorization, validation and secure information transfer, as well as management, publication and discovery of standardized information services, may benefit a large number of maritime stakeholders within different areas of application, Fig. 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.

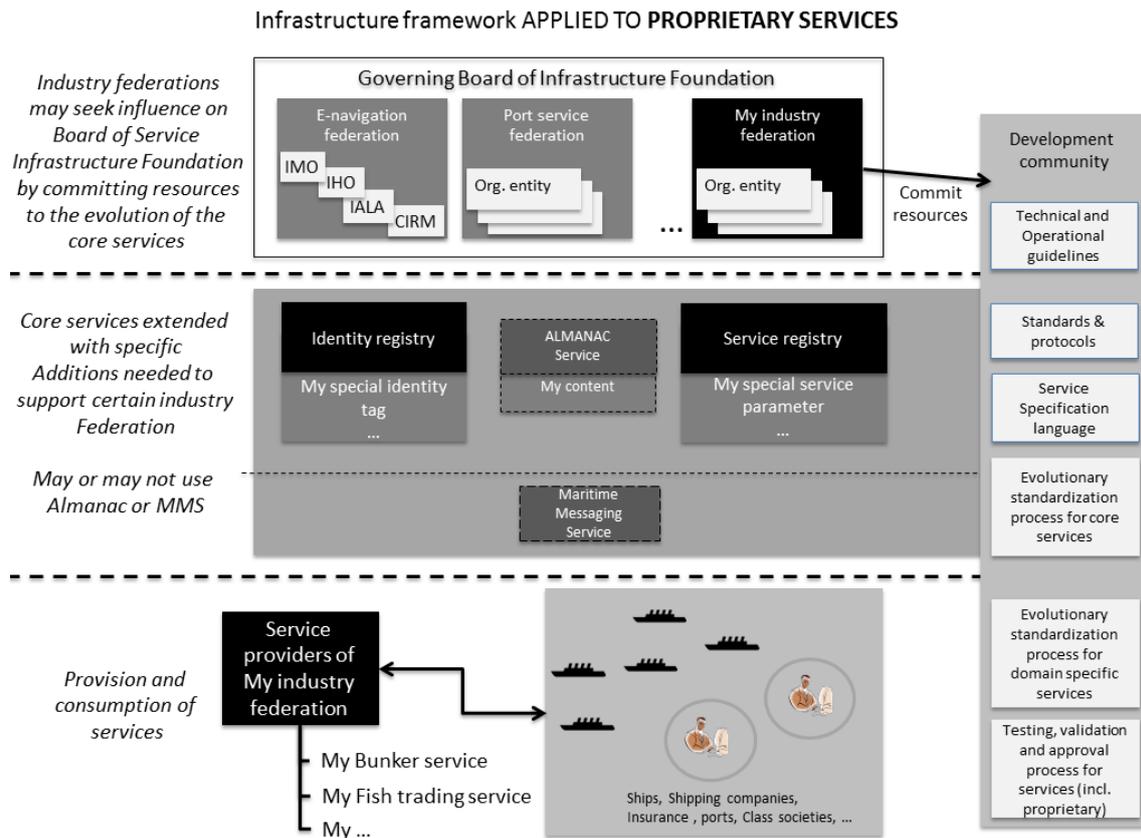


Fig. 6: Applying the service infrastructure to market demands

The infrastructure framework supporting a market place for applications, data- and communication services, service interactions, seamless roaming and information sharing

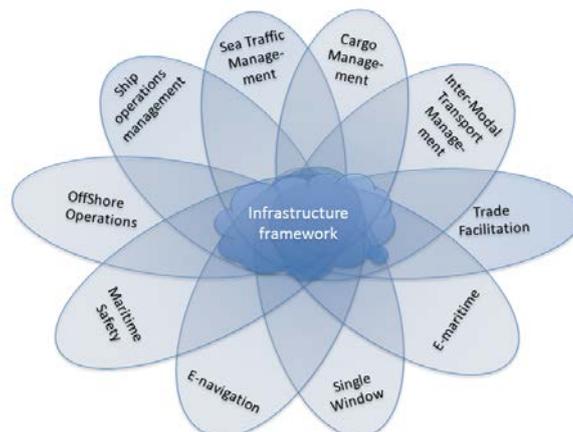


Fig. 7: The digital infrastructure framework at the intersection of maritime activity

The proposed framework is a synthesis of the efforts brought forward in the development of the Maritime Cloud and SeaSWIM concepts. This infrastructure framework will be established during 2016-2018, and will evolve and be available for service demonstration and validation until 2018 within different domains, among which the e-navigation domain is one of them, but long term sustainability depends on the success of efforts towards establishing a governing community.

4. Maritime Service and Communication Infrastructure Framework for STM

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 Fig. 8.

MARITIME SERVICE INFRASTRUCTURE FRAMEWORK FOR SEA TRAFFIC MANAGEMENT

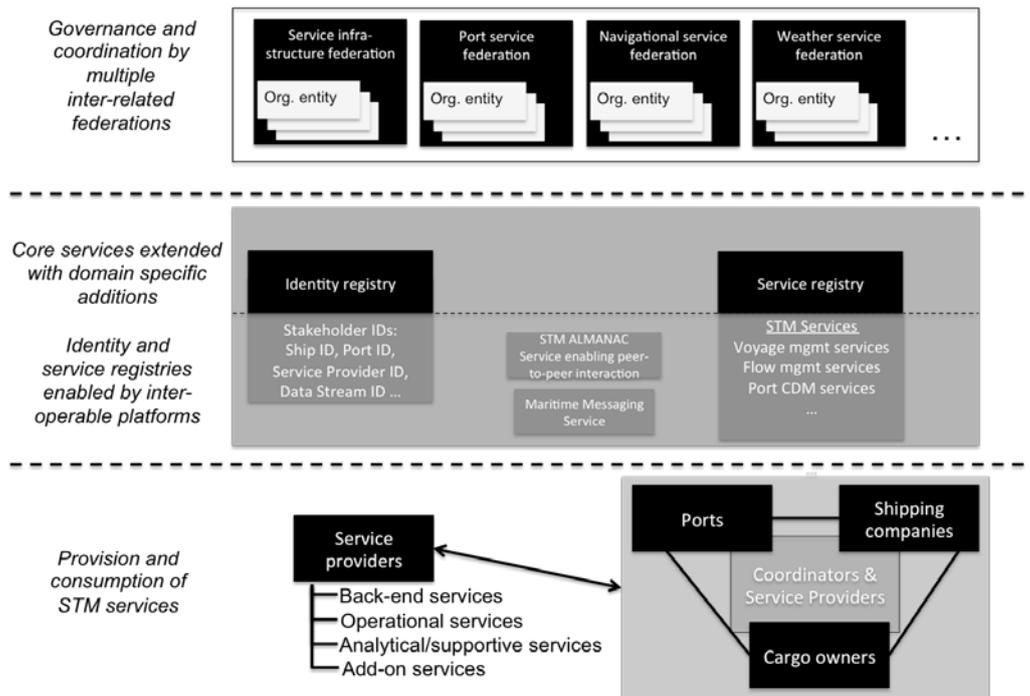


Fig. 8: Maritime service infrastructure for Sea Traffic Management

4.1 Distributed service provision and discoverability for STM

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. vessels), and other service providers. These identities provide access to services building on diverse information sources.

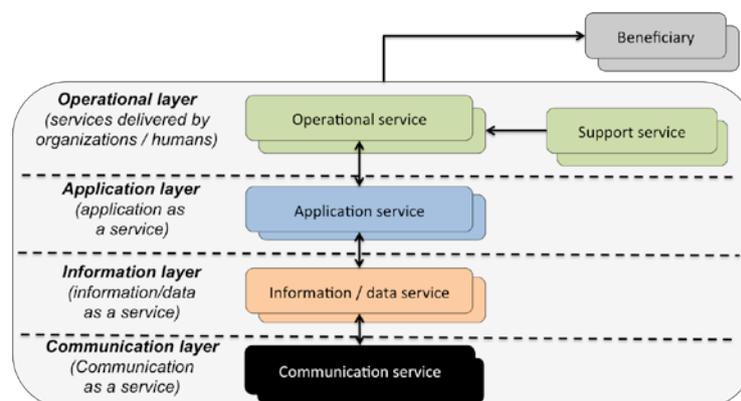


Fig. 9: Layered service framework for positioning different types of services in STM

Within Sea Traffic Management, the notion of services is built upon a multi-layer framework, Fig. 9, where the role of digitization may play different roles without losing the human agency. 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 platforms, such as the STM app store, capturing possible STM services, *Jensen 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 is a representative of. By changing one layer it should mean minimal or no impact on the other layers.

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.

As stated in the introduction, a key enabler for allowing 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, it is vital to bind the information to an identifier. The basic strategy for the deployment of a universal voyage_id is to settle a standard for the composition of the voyage_id and then let each organization that consume STM services that require the voyage as an identifier use that. At this stage the strategy is to have a standard to allocate a voyage_id that is bound to the organization and then let the organization connect use a number series when a new voyage id is needed. This is a solution similar to the product code (EAN codes), which would allow that a shipping company can different voyage_id’s for one (from port-to-port) or several legs (including visits to multiple ports). This means that the use of voyage_id could be adapted to the way that the shipping company conceive the constitution of a sea voyage.

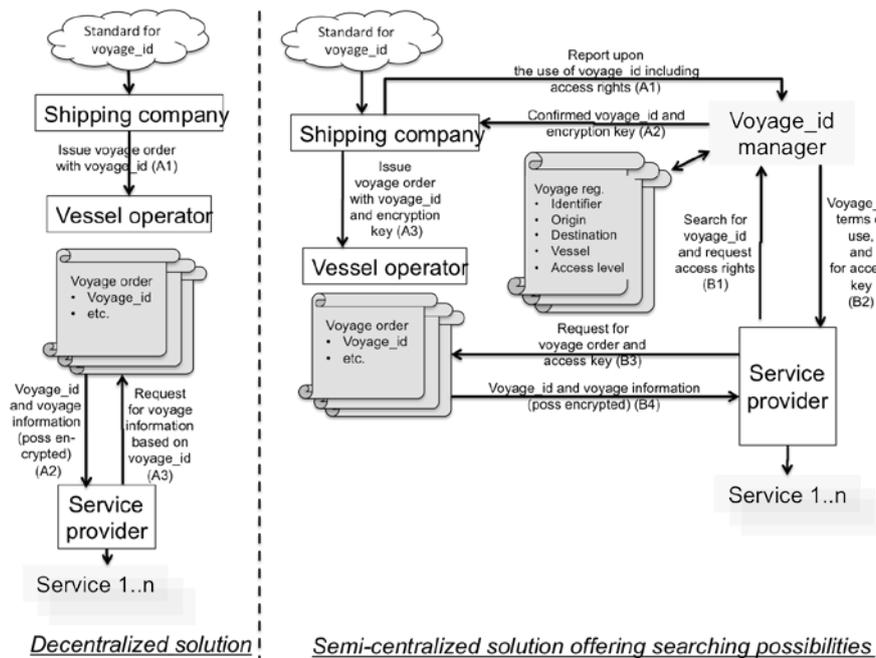


Fig. 10: Decentralized and semi-centralized as complementary solutions to the management of unique voyage_id

Two different, complementary, strategies for the implementation and use of voyage_id are considered. If the voyage_id is solely to be used as a basis for the interaction between the shipping company/vessel operator and the service provider, a distributed solution is preferred, (left part of Fig. 10). The distributed solution is a first step towards the implementation of a unique voyage_id for the maritime industry.

A complementary solution is the introduction of a voyage_id manager service keeping track of all assigned voyage_ids enabling search possibilities for service providers planned, ongoing, and conducted voyages (right part of Fig. 10). One or several trusted service providers manage the voyage_id registry. Using a particular voyage id with adjacent access keys specified in the voyage_id registry will enable access to information about the voyage. In this way, diverse service providers will have possibilities to access, store, and use voyage information in their service provision. This semi-centralized solution is to be seen as possible development step building on the distributed solution. Information about the voyage will consequently exist in the hands of multiple service providers. In order to keep track of who has information about a particular voyage, service providers need to allow search possibilities for service consumers of particular voyage_ids. The latter is a typical example of rules and regulations that the service provider needs to respond to when searching for approval for such type of service. The approval process is one task to be managed by the federation (see below) in its service portfolio management.

When a service has been discovered by a service consumer, contact can be established between service provider and service consumer and foundations for coming to agreements of the service realization can be established. Relationships between provider and consumer are in this way established. The shipping industry is 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). *Watson and Boudreau (2011)* have formulated the principle of episodic coupling principle as follows:

“The disparate systems and individuals within society can coordinate their actions through the sharing of information about those episodes when they want to interact, such as catching a bus, going to the cinema, and finding a convenient flight. The two entities want to coordinate their actions for an episode or an event”. This means that the distribution of data about intentions, as e.g. when a certain waypoint is expected to be reached, becomes essential together with status updates, as e.g. when a waypoint is reached. *Watson and Boudreau (2011)* further claim “having the ability to learn what other entities are doing across a wide variety of timelines, from seconds to years away, enables people and enterprises in a highly decoupled society to coordinate their actions. Often this coordination is invisible to one of the parties, and there is no reason for it to be visible”. This would then mean a need for integration between the different actors, such as e.g. the vessel operator and the port of destination. Centralized service and identity registries enable the coupling. 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).

4.2 The role of federations for Sea Traffic Management Services

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 a 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. 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]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.

4.2.1 Service approval and service portfolio management

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 e.g. Apple appstore). Approved services will have a “quality-mark” as a STM-service as way to show consumers that the service meets the 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.

This means that standards play an essential role in this world of distributed service offerings. However, to avoid coming into time-consuming and detailed standardization processes as e.g. making universal information reference models, 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 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.

In the efforts of defining Sea Traffic Management it has been essential to standardize a route exchange format to be included in the ECDIS 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. 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.

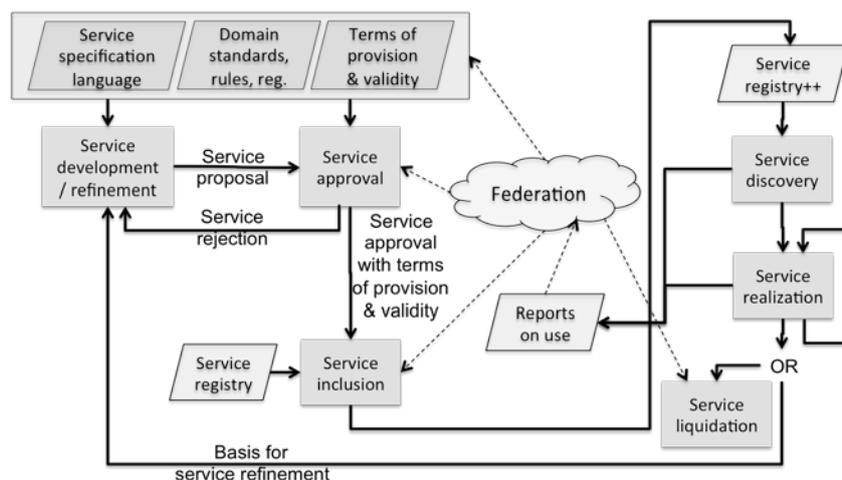


Fig. 11: The role of the federation in the service lifecycle

As depicted in Fig. 11, 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. As e.g. it is natural that IALA is embodied 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 core services of Sea Traffic Management meet enough quality
- Collect judgements and reports from the use of services as a basis for opportunity identification, and refinement, and exclusion, of services

By a federative approach services claimed to realize the Sea Traffic Management can be trusted by the service consumers. For this purpose 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.

4.2.2 Continuous monitoring, improvement and quality assurance

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. Fig.11 shows the role of the federation in the service lifecycle is depicted.

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

- First of all, services are requested which means that the federation can get continuous reports on which, and how often, particular services are requested for
- Second, if a potential voyage_id manager service is introduced it would serve as a collector of the number of voyages being connected to the STM-network and services using information about the specific voyage.
- Third, reports on service realization built into the terms of approval could be channelized to the federation for evaluation
- Fourth, reports from the community about the quality of services should be provided to the federation

5. Final remarks

Sea Traffic Management is one possible domain for the application of a maritime infrastructure framework. In this short information paper, the instantiation of this generic framework has been brought forward for the purpose of understanding necessary infrastructural requirements enabling trustworthy service provision and consumption in Sea Traffic Management. It is to be noted that Sea Traffic Management is one domain of application for a generic service infrastructure framework. The full potential and large-scale implementation would come when the same maritime infrastructure framework is applied in different areas of application that rely on information sharing, service interaction, and (digitized) actor collaboration. Examples of such (overlapping) areas would be cargo management, inter-modal transport management, and e-navigation.

Contrary to hierarchal governance, the federated approach could be applied for facilitating a market-driven approach to service provisioning. This market-driven approach is portrayed in two ways; needed operational services for sustainable sea transports are exposed to service providers to bid on, and the same kind of informational services in the service repertoire could exist in multiple instances. The market will decide the use of them.

References

CASCHILI, S.; MEDDA, F.R. (2012), *A review of the maritime container shipping industry as a complex adaptive system*, Interdisciplinary Description of Complex Systems 10/1, pp.1-15

COWI (2013) *Administrative burdens in the maritime sector*, Danish Maritime Authority
<http://www.dma.dk/publications/documents/summaryreport.pdf>

JENSEN, J.K.; LIND, M.; PARK, J.H.; LEE, K.; SETTERBERG, P. (2015a), *A maritime infrastructure framework*, ENAV16-9.22, IALA, Paris

JENSEN, J.K.; LIND, M.; PARK, J.H.; LEE, K.; SETTERBERG, P. (2015b), *How the maritime cloud supports e-navigation*, ENAV16-9.23, IALA, Paris

LIND, M.; BRÖDJE, A.; WATSON, R.; HARALDSON, S.; HOLMBERG, P.E.; HÄGG, M. (2014) *Digital Infrastructures for enabling Sea Traffic Management*, 10th Int. Symp. ISIS, Hamburg

WATSON, R.T.; BOUDREAU, M.C. (2011), *Energy Informatics*, Green ePress