From digital twin to maritime data space: Transparent ownership and use of ship information

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Abstract: *The concept of the digital twin is gaining momentum in the maritime industry, but it brings with it new questions about data ownership and governance. Given the wide range of different data that can be stored in the digital twin, it is not clear if all these data can be stored in the same data base or even use the same governance model. Within the Industrie 4.0 framework, a concept called "Industrial Data Space" (IDS) has been developed to cater to these problems for land-based industry. With the advent of "Shipping 4.0" as the Industrie 4.0 of the seas, we propose a similar concept as IDS for the maritime world, called "Maritime Data Space" (MDS). This will be an extension of IDS but will be adapted to the specific nature of shipping and, hence, a modified digital trust framework, lower connectivity for ships at sea and the highly heterogenous control and physical systems architecture on ships. However, MDS will still be a part of the IDS ecosystem and gain benefit from the further developments in IDS and its applications.*

1. Introduction

In the land-based production industry, Industrie 4.0 is now established as the fourth industrial revolution after mechanized power, mass production and computerization. As the shipping industry previously has adapted to and made use of the results from the different industrial revolutions, it is now in the process of entering what we can call "Shipping 4.0" (Figure 1, [1]). Availability and management of high quality information is a central part of the concept and will appear in applications such as simulation and optimization, augmented reality, data analytics and robotics and automation.

Figure 1. Shipping 4.0 [1]

The "digital twin", as a general concept, originated around 2000-2005, see e.g.[2]. The digital twin is a digital representation of a physical system, usually including additional contextual data, production details and other information. This allows the system owner or service providers to use the digital twin as a virtual version of the system to plan future actions or to do simulations or other analyses to, e.g. assess status of the system or to predict future problems or possibilities when the system is in operation. The concept has been extensively used in aerospace and has in the last few years gained momentum in the maritime industry. As the commercial and operational benefits of the digital twin becomes apparent, more and more different information types is being added to it. A few examples of information that can be included are:

- Construction drawings, control system designs
- Hydrodynamic and strength analysis data, tank test measurements
- Sea trial results, in-sea performance data
- Inspection data and analysis results
- Measurements from technical equipment or structures
- Operational data such as fuel consumption, speed, actual weather data etc.

However, it is not obvious that all these different information types need to or even can be stored in the same physical data base. Neither is it clear that they shall be under the same ownership and access regime. This problem is also encountered in Industrie 4.0. Here, the concept of "Industrial Data Space" (IDS) has been introduced to provide a solution to these problems. It is based on open standards and a common governance model to enforce ownership of data in a distributed environment, while making the information easily available for any trusted party.

This paper will discuss a proposal to extend the IDS system into the maritime domain under the name "Maritime Data Space". The concept of an MDS was first published by von Lucas in April 2017 [3], but was concurrently being investigated and developed further by researchers at SINTEF in Norway.

2. Why maritime is not identical to industrial

When adapting IDS to the maritime environment and particularly to ships, the possible impact of several shipping specific factors needs to be considered.

2.1 Connectivity

Ships do not have the same connectivity as land-based process plants. Communication is normally via geostationary satellites and this will always give a latency of minimum 700 milliseconds for a round trip message. More importantly, this latency can have a high variance [4], which can create problems for TCP/IP and other transport protocols. Also, the capacity of most commercial satellite communication services is limited. For merchant ships one will normally not see higher capacity than some hundred kilobits per second. More is certainly possible, but today, the cost of higher bandwidths will in most cases be prohibitive.

This means that one must take care when transmitting large data sets from or to the ship. In many cases, one will depend on decimating the data sets before they are sent and wait with a full data transmission until the ship is in port with access to high capacity land-based communication services. In addition, the impact of latency and variance in latency must be considered in the design of data management protocols.

2.2 Ship system complexity

Ships are in practice sailing villages with all public services that we would normally find in a city, e.g. energy distribution, heat and ventilation, water and sewage, local and external communication and so on. In addition, it has control and monitoring systems for energy production, propulsion and steering, navigation, fire alarms and other safety systems and so on. These systems are not normally provided by the same manufacturer and this creates problems in integration of data sources as well as ownership to the data that is collected.

Today's ships also have an expected life time of around 30 years and computer systems must be expected to be replaced several times over this life span. This creates additional problems with system interfacing and interconnectivity.

Some solutions are emerging from the international standards organizations, e.g. for navigation [5] and machinery data [6]. However, the interfaces specified in these standards must be developed further to allow full use of planned MDS functionality, e.g. for authenticity and ownership assessment.

These issues also need to be taken into consideration when adapting the IDS framework to maritime use. It may in some cases limit the functionality that can be provided by the framework and as a minimum, they will have impact on how fast these functionalities can be offered.

2.3 The international nature of shipping

Shipping is arguably the most internationalized business in the world. A ship can be flagged in any of the signatory countries to the SOLAS convention and it can sail to any port in the world, generally under the same international regulations. Owners, managers and charters can likewise be in any of these countries. Equipment manufacturers, yards, class societies and other service providers will likewise be spread all over the globe.

This creates some challenges in establishing standards and frameworks that can be used transparently between the relevant parties. One challenge is the dependence on open and internationally accepted standards for interfacing the MDS framework to any ship and all the ship systems involved. Another challenge is that IDS and MDS will depend on a digital trust framework that can be used internationally and on low bandwidth Internet connections. However, the latter issue is closely related to and can benefit from the introduction of electronic data exchanges in IMO instruments, e.g. through the Facilitation Committee and the use of Single Windows as well as in emerging e-navigation solutions. It has already been proposed to establish an international Public Key Infrastructure (PKI) for the maritime community, coordinated through IMO [7].

These issues will also create some constraints in how IDS can be modified to fit the maritime domain.

3. Overview of IDS

The industrial data space[1] (IDS) [8] is a virtual data space leveraging existing standards and technologies, as well as accepted governance models for the data economy, to facilitate the secure and standardized exchange and easy linkage of data in a trusted business ecosystem. It thereby provides a basis for smart service scenarios and innovative cross-company business processes, while at the same time making sure data sovereignty is guaranteed for the participating data owners. The system is fully decentralized and does not depend on any centralized or proprietary data repositories or services.

IDS allows data to be stored at different locations, in different formats and with different access mechanisms and protocols. The Connectors (see Figure 2) will hide these technical

[1] https://www.internationaldataspaces.org/en/

interface details from the users of the framework and will also implement the security mechanisms that safeguards data from illegal access while providing an open and transparent framework for verified data users.

Data is only exchanged if it is requested from trustworthy certified partners. The data owner – ship owner, class society, equipment manufacturer or other – determines who can use the data in what way. As a result, the partners to some ship operations can have joint access to certain data by mutual consent so that they can start something new, develop new business models, design their own processes more efficiently or initiate additional added value processes elsewhere, either alone or together.

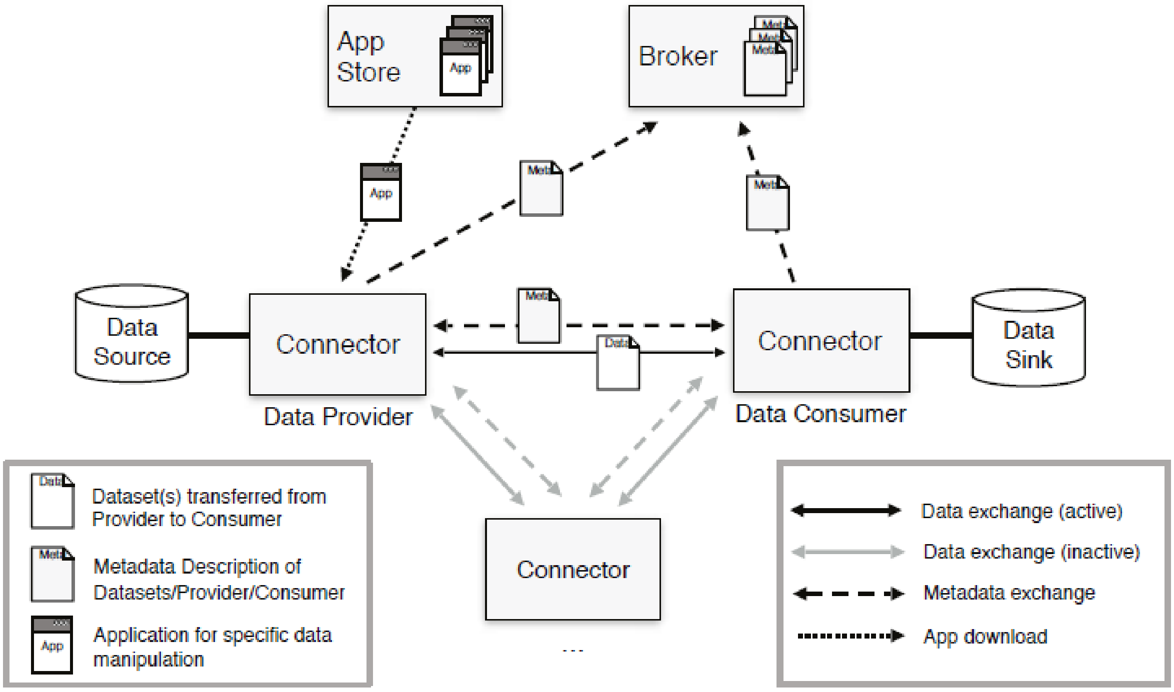

Figure 2. Interaction of technical components in IDS

There may be different types of implementations of the Connector, based on different technologies and depending on what specific functionality is required. Two basic versions are the Base Connector and the Trusted Connector. The Base Connector is used for interfaces to the open IDS framework while the Trusted Connector can be used in in-house applications where security is already ensured.

There are extensive security mechanisms implemented in IDS. In addition to allowing secure identification of parties, it can also support other security attributes, e.g. "reputation", "current security state", and it can support payment models where service provision or data access is dependent on a commercial business model.

Connectors can also implement various types of functionality that allows pre-processing of data. For ships, it may be useful to implement conditional decimation functions to better control bandwidth usage. The running of certain connector functionality can also be linked to the security functions.

IDS also contains provisions for implementing application provision from third parties, i.e. one or more "App Store". If needed, one may also make use of data brokers to implement more advanced forms of data protection and anonymity. This could, e.g. be useful for more advanced benchmarking functions over many owners' ships where parts of the benchmarked data contain business sensitive information.

4. Proposed conceptual model for MDS

More and more digital ship data is produced on board or onshore related to the ship, from increased digitalization and cheaper sensor technology, but also from yards, ship equipment vendors, interest organizations, class societies and authorities. To make use of this data, new service providers want to offer new functionalities related to data analysis, customer empowerment, automated reporting, process improvement and quality monitoring. Today, data sharing with service providers is done on an ad hoc basis where the data access agreements must be negotiated case-by-case and often involving several different parties. We propose to use the IDS mechanisms to develop a new open framework for data management in the maritime business field: The Maritime Data Space (MDS).

The proposed conceptual model for "Maritime Data Space" (MDS) is illustrated in Figure 3. It will be implemented from the IDS model. The conceptual model shows how it will appear to the users.

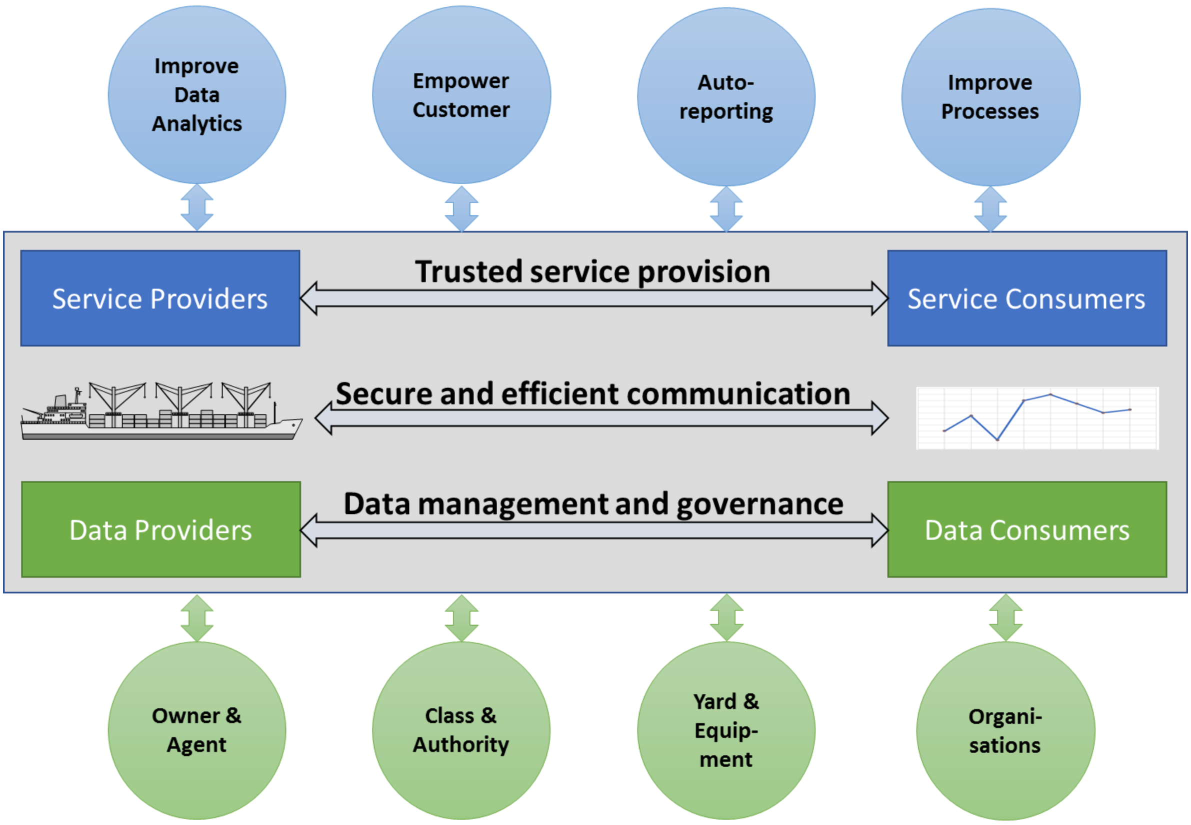

Figure 3. MDS conceptual model

Data Management and Governance: Ship information will be provided and often locally stored by yards, equipment manufacturers class, flag state, owners, operators and many other parties. Since data is often produced and owned by other parties than those providing services based on the data, a new model for trusted sharing of data is needed. We want a model where the data owner(s) directly control access rights, independently of where the data is stored. In the maritime sector, no such standard mechanisms exist. Thus, we propose to adapt the Industrial Data Space (IDS)" initiative to the maritime environment. IDS is being developed over several automation domains, generally land based, to provide a standardized and secure way of managing data ownership and access rights in these domains. Principles from IDS will be combined with the current developments in maritime communication technology and cyber security, and the result will be a new data and service integration concept for modern shipping.

Secure and efficient communication: User authentication and authorization, secure data transfer and proof of data owner ship (trusted identity) will be implemented through the new Public Key Infrastructure (PKI) proposed by the CySiMS project[2] [7]. With the secure data transfer, an advanced file transfer protocol optimized for the maritime domain will be implemented which leverage the deduplication engine developed in Seadrive [10]**Fehler! Verweisquelle konnte nicht gefunden werden.**. This allows MDS to provide reliable and efficient data transfer and file synchronization over high-latency, low bandwidth networks, even in the face of high rates of packet loss. Distributed information storage and service provision require efficient and secure communication, often over limited bandwidth and long latency satellite data links.

Trusted service provisions: As information may be distributed, even regarding who owns the data, there must be mechanisms in place to securely and efficiently allow third party service providers to access the data. MDS development is starting up now and will include several pilot cases selected by the industry partners as being representative for the next generation of digital ship services. The planned cases are shown on the top part of Figure 3. These cases will show the easy and secure realisation of these new maritime services with focus on distributed management and governance of ship related data using digital contracts and secure communication.

MDS will define a new and open "digital ecosystem" for the maritime community where data can be made easily, efficiently and securely available and where new and improved services can be developed and deployed on an open and distributed platform.

5. Development of MDS

The MDS development project starts in the fall of 2018 and is planned to last for two years. As much of the infrastructure is already available from IDS, the developments will focus on the following issues.

Maritime Data Space development: Adaption of the IDS framework to the maritime environment. The main issues here were discussed in section 2 and this activity will focus on the public key infrastructure for the security and trust framework and the complexities of interfacing to shipboard systems. The latter is expected to have some impact on the IDS framework in terms of, e.g. quality and availability attributes for some data sources.

Effective, secure and robust communication: This is a special activity linked at low bandwidth and variable latency problems that occur when communication with ships. Various forms of data compression and protocol adaptions will be investigated.

Application developments and demonstrations: The final activity group is related to develop various test applications for the industrial parties in the projects. The planned applications are illustrated at the top level of Figure 3.

[2] Cyber Security in Merchant Shipping – CySiMS: See http://cysims.no/

6. Linking MDS to IDS developments

SINTEF is a member of the International Data Space Association and have already started the work to include MDS as one of the application areas for the IDS community. All specifications for the framework and for the relevant Connectors will be published as open standards. The work is also linked to other activities we have towards IMO, related to e-navigation and mandatory ship reporting requirements. Any developments in this area will be incorporated into the MDS framework to make it compatible with the wider digitalization of shipping that is currently ongoing.

7. Conclusions

The MDS project will develop a framework for using the Industrial Data Space technology in the maritime domain, taking into considerations the limitations that ships are constrained with. This includes bandwidth and latency, the required international focus of shipping and other factors as described above.

The project will also develop demonstrators to show that the MDS framework works and that it simplifies deployment of new digital services in the maritime domain.

MDS will also link to other ongoing developments in the digitalization of shipping. The development of a common Public Key Infrastructure for international shipping will be important.

MDS specifications related to IDS adaptions will be made publicly available through IDS and other standards organizations.

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