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Internet of Things at Sea: Using AIS and VHF over Satellite in Remote Areas

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Abstract

This paper describes how the Automatic Identification System - Application Specific Message (AIS/ASM) via Low Earth Orbit (LEO) satellites can be used to transmit small data between ship and shore to facilitate information visibility in future maritime transport systems. The focus is on ships without advanced satellite terminals in remote areas where terrestrial infrastructure is not available. Here, AIS is proposed as a low cost and general alternative to ordinary satellite communications. In this paper, we report on how reliable ASM is for data exchange, for instance for cargo-monitoring data. One problem is to determine when the LEO satellite is in a geographic position to receive messages from the ship. Another problem is that the AIS satellite can fail to register data, even when in the radio range of the ship, because the ship antenna is constructed for horizontal radiation and sends very little signal upwards, especially when the satellite is at its closest to the ship. The study uses AIS data from the Norwegian Coastal Administration to determine the probability that specific AIS transmitters are detected by the satellites.

Keywords: Automatic Identification System (AIS), Internet of Things (IoT), VHF, Satellite Communications.

1. Introduction

Industry 4.0 has been defined as "a collective term for technologies and concepts of value chain organization" which draws together Cyber-Physical Systems, the Internet of Things and the Internet of Services. As with the other industrial big changes such as steam and computer automation, one can already see that Industry 4.0 technologies are picked up on ships and in shipping. This can tentatively be called Shipping 4.0 as illustrated in Figure 1. Availability of reliable and secured telecommunications also in remote areas is a prerequisite to be able to implement Internet of Things and Internet of Services for maritime transport. There is an increasing need to have online monitoring information, also from ships without satellite communication, to integrate this information into supply chains and other systems. Since the portion of the world fleet that have satellite terminals is relatively low (about 30%), while almost all vessels in commercial operation carry AIS transceivers, we propose to use AIS/ASM as a low cost and general alternative to ordinary satellite communications in remote areas or any areas having difficulties in doing communications over general traditional radio methods.

Offering communication capacities in difficult conditions is a prerequisite for collection of information during the whole transport chain. Further, being able to collect and distribute information during the whole transport chain is important to be able to provide visibility to the transport chain actors. From deliverable SELIS D2.1 Green Logistics Strategies and Capabilities [1], which contains descriptions of the European Green Logistics Strategies (EGLSs), we know that Supply Chain Visibility and CAPA Visibility is a strategic capability that is highly relevant for communication in difficult conditions.

It states the following: *"Visibility is a prerequisite for transport planning, execution and monitoring. Lack of visibility hinders supply chain agility and transport and logistics performance. Transport planning processes such as the planning of transport capacity, the allocation of cargo to available transport capacity, and route planning, are highly dependent on accurate and timely information. During transport execution, information on the condition of infrastructure, traffic, availability of resources, and information on status of cargo at the shipment and consignment levels, is relevant. Monitoring (and re-planning) is highly dependent on visibility. It allows for the detection and signalling of anomalies and deviations from the plan. It provides the ability to foresee such deviations by estimates of the probability of occurrence, and detect deviation at an early stage. It also creates the ability to evaluate and select corrective actions such as re-schedule or switch to another resource, asset, or service. As such, visibility helps increase the predictability of events"* [2].

Figure 1 – Concept of Shipping 4.0
[Source: SINTEF Ocean]

To summarize, this means that the availability of communication services also in difficult conditions is important as an enabler for visibility of future supply chain. The next section describes data requirement with focus on a future logistic platform to be developed by the EU project SELIS [3].

1.1. Data Requirement

By analysing the eight Living Labs in the SELIS project, we found a set of relevant data to be communicated during the transportation. Only data used in the planning and execution phase need to be handled since we assume that this covers communication in difficult conditions. We assume that during marketing, sales and completion of the transport, the communication technology is in place. Further, only data that is used during operational planning is relevant, not during strategic and tactical planning. However, information related to goods monitoring is the most important for our case. New introduced legislations and high-end markets are pushing towards a more meticulous and exhaustive monitoring of goods transport, constraining the logistics sector to adopt and be open to new technologies that might offer these services in a handier and easier way. Goods monitoring will provide better customer experience, detection of hostile storage environment, detection of loss of goods in transit, reduce theft and reduce breakage due to improper handling. Cargo tracking and monitoring in maritime transport requires the possibility to have connectivity of the ship also in remote areas. It requires that the connectivity is not only dependent on satellite communication, but also that simpler communication modes with smaller bandwidth can be used, for instance using the ASM (Application Specific Messages) channel provided with the AIS satellites. The issue of having constant connection for ships when operating in remote areas is relevant for several use cases:

- **Transport re-planning based on monitoring of the shipment**: Knowing the position of the cargo during the whole transport, also during the maritime transport leg, will ensure the possibility to achieve real-time and short-term transport re-planning.
- **Cargo re-routing based on monitoring of the cargo condition**: By continuously knowing the status of the cargo, the responsible party will be able to take actions before the cargo either is damaged, by intervening on the cargo or re-route the cargo because it is perishing more quickly than foreseen.

In addition to this, we have the case when monitoring the ship's position, where constant connectivity is important to contribute to more effective and correct transport resource management.

2. Telecommunication Systems on Ships

Ships are dependent on satellite communication when out of range of coastal systems. There is a wide range of satellite communication systems available. Very roughly, they can be categorized as in Table 1. The band column refers to radio frequency used, most commonly from L-band (1 - 2 GHz) and C-Band (4 - 8 GHz) up to Ku (11.2

- 14.5 GHz) and Ka (26.5 - 40 GHz) bands. The range refers to IMO's (International Maritime Organization) sea areas A1 (coastal VHF range), A2 (medium wave range), A3 (high seas without Arctic) to A4 (Arctic). Bandwidth is typically measured in kilobits per second. Terrestrial radio systems may have a visible limitation in coverage comparing to the case with satellite. For instance, a WiFi system is only usable around the ports or inside the vessels. WiMax works similarly with WiFi but can reach to a larger distance between 10-15 km from the port [4], [5]. The newer mobile communication system such as 4G/5G system is only eligible to use when it is in the coverage of base stations, Figure 2. Satellite communications can provide much larger coverage but only Low Earth Orbit (LEO) or Medium Earth Orbit (MEO) satellites can fulfill a global coverage (fully covers the areas A1-A4). GEO satellites can provide a better bandwidth comparing to LEO/MEO's but it has more constraints on the coverage (e.g. it covers up to area A3 and not A4). For applications requiring global coverage and not high bit rate or bandwidth, LEO/MEO based satellite system is therefore most preferred. Satellite systems have large coverage but it still exists areas that satellite is not reachable (e.g. with GEO satellites) or service is not stable (e.g. with LEO satellites), for instance in the high north regions. As a result, a new system that can provide a reasonable communication capability in such situation is necessary and that is the purpose of this paper. This new system should be hybrid communication system that use satellite's large coverage when terrestrial is out of reach and it relies on terrestrial system when it is in range. Moreover, to be usable for a large portion of the world's fleets, this new system does not need a proper satellite transceiver as Inmarsat/VSAT or Iridium.

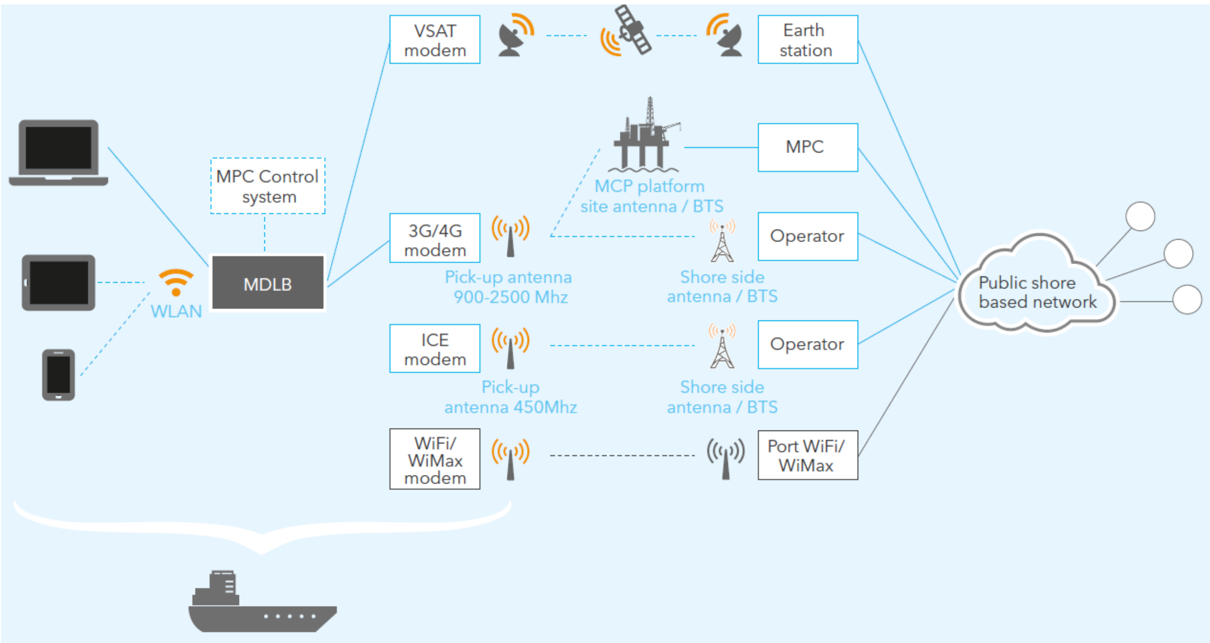

Figure 2 – Full description of telecom architecture on a modern vessel [Source: [6]]

In this study, we propose to use AIS/ASM, which operates based on VHF (Very High Frequency) radio communications, and it therefore does not require a satellite transceiver. Traditionally, the AIS system on the vessels will periodically transmit so-called AIS messages to authorized organizations, for instance Coastal Administration (in Norway) where these messages will afterwards be shared with relevant parties. They include both dynamic (e.g. positions, speed, course) and static (e.g. the vessel's relevant information) message types. The aim of AIS base stations is to detect those messages before the information is shared amongst other AIS base stations and vessels in vicinity. At the same time, these AIS messages can also be detected by AIS satellites (e.g. AISSat-1/2 of Norway specifically launched for the high north regions or global commercial Orbcom satellites[*]) when the vessel is in that satellite's range.

The most challenging is that AIS antenna on the vessels aims to communicate horizontally with a base station, so it is interesting to find the percentage of the messages detected by AIS satellite compared to what is detected by AIS base stations. This will be one of the main discoveries in this study, and we will provide detailed information and analysis on this in chapter 4.

[*] https://www.orbcomm.com/en/networks/satellite-ais

Table 1 - Typical communications options on board a vessel

System	Orbit	Band	Range	Bandwidth	Comment
Inmarsat C	GEO	L	A3	9.6 kbps, packet oriented	GMDSS, Used for short e-mails and messages
Inmarsat Fleet 77/BGAN	GEO	L	A3	128-450 kbps	GMDSS (not BGAN yet), supports Internet
Iridium	LEO	L	A4	134 kbps (Open Port)	Have coverage in Arctic.
VSAT shared link	GEO	C, Ku, Ka	A1-A3	Any, typical 64-512 kbps. Shared by several users.	Coverage varies with system, normally not deep sea.
VSAT dedicated link	GEO	C, Ku, Ka	A1-A3	Any, dependent on price. Dedicated capacity to user.	Coverage varies with system and (high) price.
Others (Orbcomm, Globalstar, Thuraya, ARGOS)	LEO	L, S, C, Ku, Ka	A1-A4	Typically, low and usually up to telephone.	Either bent pipe systems or store and forward.

Service Optimization

Sending messages over AIS/ASM can in many cases be combined with using other satellite communication means or terrestrial communications when the ship is close to shore or in satellite range. As more and more communication options have become available, it has become more difficult to select the optimal communication bearer as they have different capabilities and characteristics. In addition, the availability of a certain carrier will vary according to the position of the ship, weather conditions and the actual traffic situation. On the other hand, the applications and services must be able to select the best communication carrier at each time, since the application and services have diverse communication needs. The requirements for reliable and efficient communication with the lowest cost must be compared and matched with the available communication channel characteristics. The requirements from the logistics applications must be matched with the different available communication carriers, and then, routing to this telecommunication service provider must be done. An overview from SELIS is given in Figure 3:

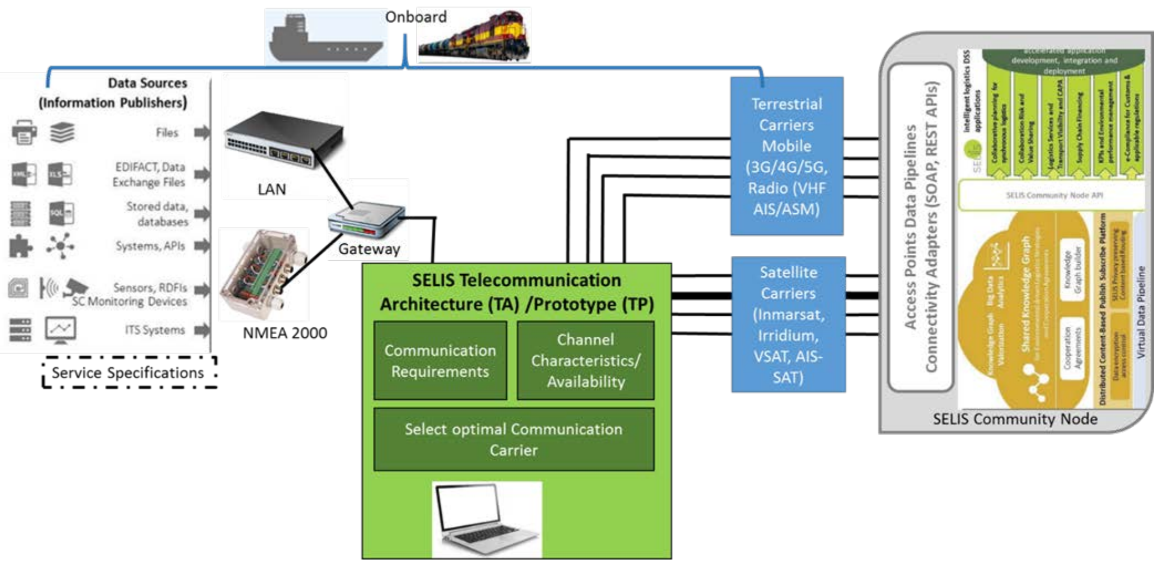

Figure 3 - SELIS Telecommunication Architecture (SELIS TA) and SELIS Telecommunication Prototype (SELIS Project. [Source: SINTEF Ocean])

- Data sources, left part of Figure 3: Meta-data from the logistics applications and other services describing the requirements these applications have regarding communication.

- Channel characteristics, blue boxes in Figure 3 covering terrestrial and land-based carriers: Describing and maintaining the properties of the available communication channels.
- Software tool to do the matching between application service requirements and channel characteristics and availability, selecting the optimal communication carrier based on the data transmission requirements and the channel characteristics.

The next section provides technical descriptions of AIS/ASM for sending small text messages.

3. AIS/ASM: Capability and Challenge for Data Communications

3.1. Capability for small data communications

Sending ships' position and associated information to other ships and authorized shore organizations is the main purpose of the AIS (Automatic Identification System) [7]. This information used for sharing the vessels' information especially about its position, course change, speed and trajectory for increase of safety and collision avoidance. AIS operates principally on two dedicated frequencies on AIS #1 87B (161.975 MHz, Simplex, for ship to ship)) and AIS #2 88B (162.025 MHz, Duplex, for ship to shore)). It uses Self Organised Time Division Multiple Access (SOTDMA) technology to meet the high broadcast rate. This VHF frequency has a limitation of line of sight (often at about 40 nautical miles) and it varies upon a change of heights on transmitter and receiver antennas. ASM (Application Specific Message) is an added functionality for sending messages of more general character. ASM may be sent on the same two VHF channels as the position reports (AIS channels), but recently, two new channels have also been allocated specifically to ASM (ASM channels). With a significant number of LEO (Low Earth Orbit) satellites operating commercially or by various authorities, AIS and ASM messages can be picked up in most areas of the world and forward the data to dedicated ground stations. While the capacity of each VHF channel is low (9.6 kbps nominated bandwidth), this capacity is underutilized in remote areas where ship density is low.
Following the IMO Convention for the Safety of Life at Sea (SOLAS) Regulation V/19.2.4, it requires all vessels of 300 GT and above engaged on international voyages and all passenger ships irrespective of size to carry AIS on-board (Class A). Non-SOLAS vessels (Class B, pleasure crafts) provides limited functionality. Systems based on AIS technologies are therefore becoming increasingly important in ensuring safety at sea in the coastal areas and in preventing ship collisions by providing an infrastructure to support communication between ocean-going vessels, Vessel Traffic Management and Information System, and various clients such as Port Authorities, Maritime Administration, Coast Guard, Marine Exchanges and Ship Agents.

Data transmitted on AIS is of a binary type following NMEA-183 message format, which includes

- Static Information (Every 6 minutes and on request): MMSI number, IMO number, Name and Call Sign, Length and Beam, Type of ship and Location of position fixing antenna
- Dynamic Information (Depends on speed and course alteration): Ship’s position with accuracy indication, Position time stamp (in UTC), Course Over Ground (COG)
- Voyage Related Information (Every 6 minutes, when data is amended, or on request): Ship’s draught, Type of cargo, Destination and ETA, Route plan (Waypoints)
- Short safety related messages: Free format text message addressed to one or many destinations or to all stations in the area. This content could be such as buoy missing, iceberg sighting, etc.

In coastal waters, shore side authorities may establish automated AIS stations to monitor the movement of vessels through the area. Coastal stations can also use the AIS channels for shore to ship transmissions, to send information on tides and located weather conditions. These stations may use the AIS to monitor the movement of hazardous cargoes and control commercial fishing operations in their waters. AIS may also be used for SAR operations enabling SAR authorities to use AIS information to assess the availability of other vessels near the incident. In addition, there have been many studies on how to improve the use of AIS network for various purposes in maritime domain. For instances, they can be for Vehicle Traffic Management (VTS) [8], an integrated monitoring platform for vessels [9], [10] or for an increase of safety for un-commercial seafarers [11]. However, none of them has proposed AIS/ASM framework for Internet of Things over the oceans. In AIS system, ASM is an added function with capability to operate on separated VHF channels and only for sending messages of predefined applications. Specifically, AIS has total 27 different types of messages where message No. 1-3 is for position reports and message No. 6, 8, 25, 26 is for ASM.

3.2. Data Content of AIS Messages

The most benefit of the AIS framework is that it allows transmitting data in an organised, interoperable way. It also fuses static and dynamic data together. Dynamic data includes vessel's course, speed and position, which fuses with static data including a vessel's MMSI number, its size and the destination to give a comprehensive navigation system. This data is broadcasted on two channels AIS #1 and AIS #2 to ensure the devices can have seen each other and interoperate within the AIS slot map. The AIS slot map is the gateway to ensure that each AIS product interoperates within the AIS system. This interoperability ensures the integrity of the AIS system is maintained. Different AIS products will use the slot map in different ways for instance some can reserve their slot, some sends without having a slot, whilst others scan for a free slot to transmit data into the network (see Figure 4).

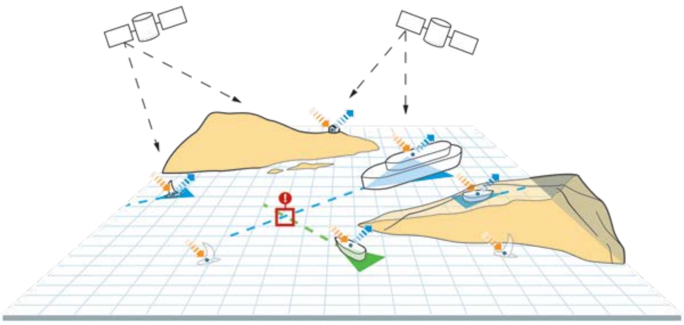

Figure 4 – AIS data messaging [Source: Allaboutais.com]

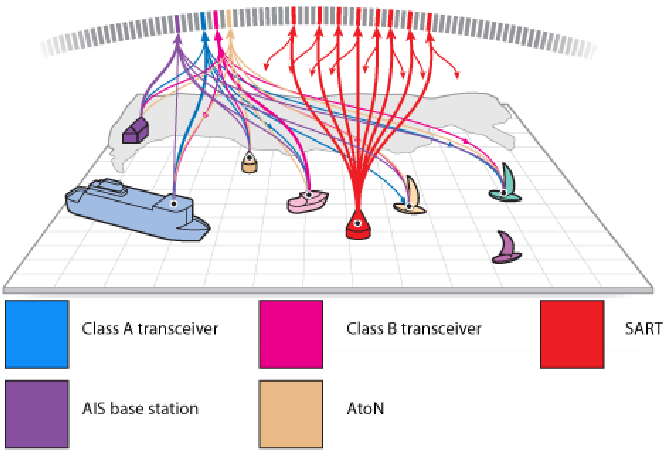

Figure 5 – Multiple access methods for AIS products [Source: Allaboutais.com]

3.3. Multiple Access Method for AIS Messages

In Figure 5, AIS class A users use Self Organised Time Division Multiple Access (SOTDMA) as its multiple access method. SOTDMA enables to reserve time slot and any subsequent time slots for transmission. Class B uses Carrier Sense Time Division Multiple Access (CSTDMA) where the users scan for available time slots in the slot map and transmit when one idle slot is found. Unlike SOTDMA, CSTDMA units are not able to reserve a slot. Fixed Access Time Division Multiple Access (FATDMA) is used by AtoNs (Aid to Navigation). This protocol ensures that the AtoN time slots are controlled by an AIS base station, and that time slots used by ships are stopped and instead AtoN data is sent and received. Random Access Time Division Multiple Access (RATDMA) is also used by AtoNs. It behaves like CSTDMA, where the slot map is not controlled by an AIS base station, so the AtoN must scan for an available space to transmit into. Pre-Announced Time Division Multiple Access (PATDMA) is used by SARTs to transmit data. The SART transmits its data regardless of the slot being reserved or not. This system is designed to be used in emergency situations so the priority is therefore higher than in the others.

3.4. Challenges of using AIS/ASM for data communications

Along with the benefits of using AIS framework in dynamic and static information reporting, the most challenging use of AIS/ASM for small data message is that the capability of being detected by AIS satellite is low. This happens because the original design of AIS antenna on the vessels was to communicate with ground based AIS stations. Another conventional limitation is that a low data bitrate of several kilobits per second is expected because of its low and narrow band. In the high north region, where solar flare activity is often stronger than in other parts of the earth, the effect on such radio is also expected.

4. AIS/ASM Data Analysis: Case study with Ferry in Ørland Fjord of Norway

The main contribution of this paper is to investigate the possibility of transmitting some binary data messages between ship and shore by using existing AIS networks. Specifically, this aims to insert some general data into ASM messages, which was defined as part of the AIS framework. Therefore, regarding the stability of data messaging, performance of AIS messaging can be used for evaluating performance of ASM. This case study focuses on the areas far from the shore (or remote). It will provide detailed analysis of how AIS messages were detected by AIS satellites. Since the selected the case is from Norway, the satellite in use will be AISSat-1/2[†] (See Figure 6). In general, an AIS message is detected by one AIS base station; sometimes it can be received by more than one base station. At the same time, this message can also be detected by an AIS satellite, which will forward it to a ground station for collecting and sharing vessels information with others. Theoretically, the rate of receiving AIS messages by satellite will be much lower than the rate of message detected by AIS base station. This is the consequences of these possible problems: a) Satellite's coverage of LEO satellite is limited such as one vessel can see a satellite only in about 8 minutes; b) Another problem is that the AIS satellite can fail to register data, even when in the radio range of the ship, because the ship antenna is constructed for horizontal radiation. It sends very little signal upwards, when the satellite is at its closest to the ship; c) There are also disturbances from electromagnetic phenomena in the atmosphere that can additionally reduce the reliability of the communication.

To see the difference between the possibilities of detection for AIS messages by satellite and base stations, this case study focuses on large sets of data collected from actual operation of a ferry in the Trondheim fjord, Norway. The reason for

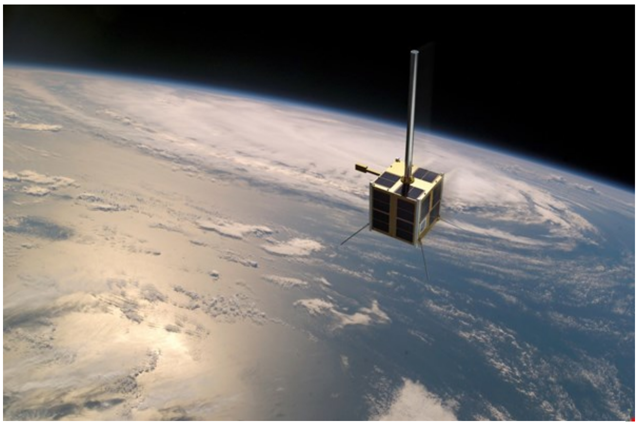

Figure 6 – AIS Satellite -1 in Norway at LEO orbit [Source: Romsenter.no]

Figure 7 – Route of Brekstad-Valset (Ørland) ferry in Norway [Source: MarineTraffic.com]

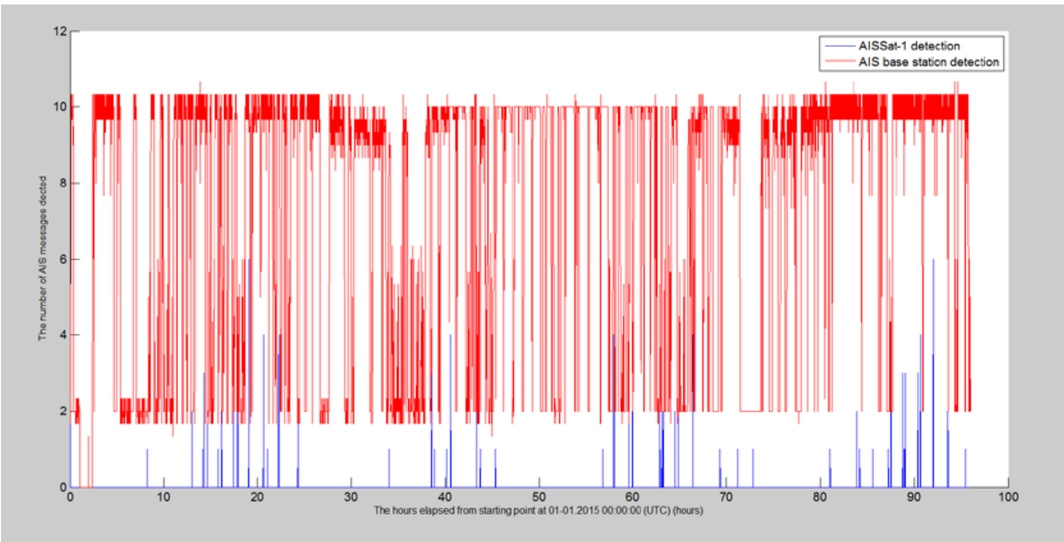

Figure 8 - Number of AIS messages successfully detected by base station and AISSat-1 (Ørland ferry in Norway)

† https://directory.eoportal.org/web/eoportal/satellite-missions/a/aissat-1-2

selecting this case is for simplicity in data analysis as the ferry moves back and forth between two positions: Brekstad (Lat/Lon: 63.686470/9.667278) and Valset (Lat/Lon: 63.638820, 9.687741). The duration of a single trip is around 25 minutes and its route is plotted with green circles, Figure 7. Note that there is one AIS base station located at Brekstad, so the possibility of AIS message transmitted from this ferry and received by this base station is high. In addition, marine traffic around this base station is not high, so collision of messages transmitting at the same time by the vehicles in its vicinity is low.

The analysis starts with a large AIS dataset provided by the Norwegian Coastal Administration's for both terrestrial (AIS base station) and satellite (AISSat-1) in January 2015. For a better visibility in the plots, only data in the first 4 days of January was used for coming plots. Dynamic data was selected for analysis from both data sources: AIS base station and AISSat-1. The total number of distinguishable AIS messages only transmitted from Ørland ferry were analyzed for the days from 01-01-2015 00:00 to 04-01-2015 23:59, Figure 8. The horizontal axis is the hours elapsed from the starting point and it ends at 96 (full 4 days of data observation). Some messages can be simultaneously received by more than one base station but only distinct messages were counted in the analysis. The amount of AIS messages in every minute of those four days is shown in Figure 8. The red lines show the number of messages per minute detected by terrestrial AIS station and the blue lines show the number of messages detected by AIS satellite (AISSat-1) per minute. The results show that during those days, 10 messages per minutes was the maximal amount for dynamic information from Ørland ferry and detected by Brekstad base station; whilst this amount is about 4-5 messages detected by AISSat-1. In average, per minute, there was around 7 messages detected by the base station and around 2 messages detected by the satellite. The ratio between these amounts is therefore about 30%, which means around 30% of AIS messages transmitting from the ferry was detected by AISSat-1. This rate can vary over time because the actual number of transmitted messages per hour depends on the course, speed of the ferry, the changes of its course, and is also dependent on the satellite's position. In general, several hours before and after midnight, as the ferry does not operate or operate not often, the number of messages transmitted in this period is minimal.

Another result from this analysis is that there are several visits of AISSat-1 per day to the area the ferry is operating in, maximum 10 times and amongst these some orbits were consecutive (cover the area after every 97 minutes). Figure 9 shows three consecutive orbits of AISSat-1 when it was orbiting from north to south and one can see that the relative position between Ørland ferry and the satellite was changing as the earth was also following its own orbit. In the other half of the day, one can also see similar pictures when the satellite passes over the ferry area but it will be moving from south to north.

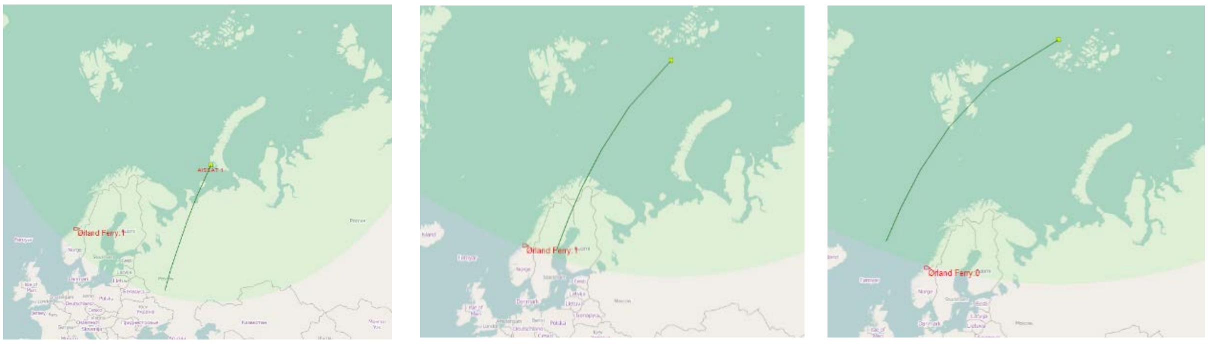

Figure 9 – Snapshots of AISSat-1 in three consecutive orbits cover Ørland ferry on 01-Jan-2015

Message latency due to satellite's movements

This relative movement between satellite (e.g. AISSat-1) and an object of interest on the earth (e.g. Ørland ferry) has a significant effect on the possibility of relaying messages down to a ground station. At present, AISSat-1 is operating with only one ground station located in Svalbard, Norway. The data message can then be forwarded to the ground station only when this ground station is covered by the satellite.

In the first half of the day, for instance, the satellite moves from north to south, and the satellite will meet the ferry (Ørland) after it met the ground station (Svalbard). If so, the detected messages will have to wait for the next time when ground station can see the satellite again as showed in Figure 10. This causes a delay that roughly equals the orbit duration (approximately 97 minutes). If the satellite both cover the ground station and the ferry, then the delay will be minimal because the delay is only the time for the satellite to forward the message to the ground station. So, the delay due to relative moving direction between ground and satellite can ranges from several minutes up to one cycle duration of the satellite orbit. In the opposite case, when the satellite moves from south to north, then the messages should wait for a short period for the satellite to move from Ørland to Svalbard where the ground station locates. In fact, this period is only counted in minutes (for an example, at the time on Figure 10, the delay was about 7 minutes).

Delay due the limitation of satellite's coverage (at not high latitudes)

In addition to the delay due to satellite's movement, there is another delay caused by the limited coverage of the satellite. The Svalbard ground station located at 78.216ºN 20ºE can see the satellite in every orbit or in every 97

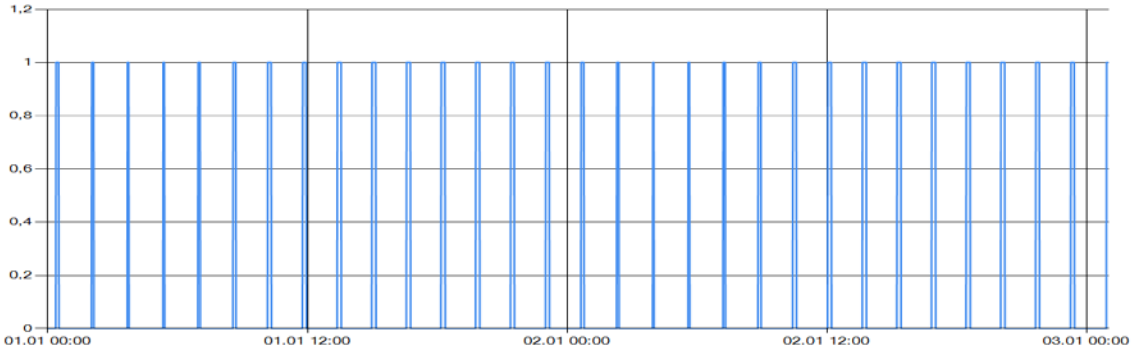

Figure 11 - Periodical coverage of AISSat-1 at Ground station (Svalbard) [Source: SINTEF Ocean]

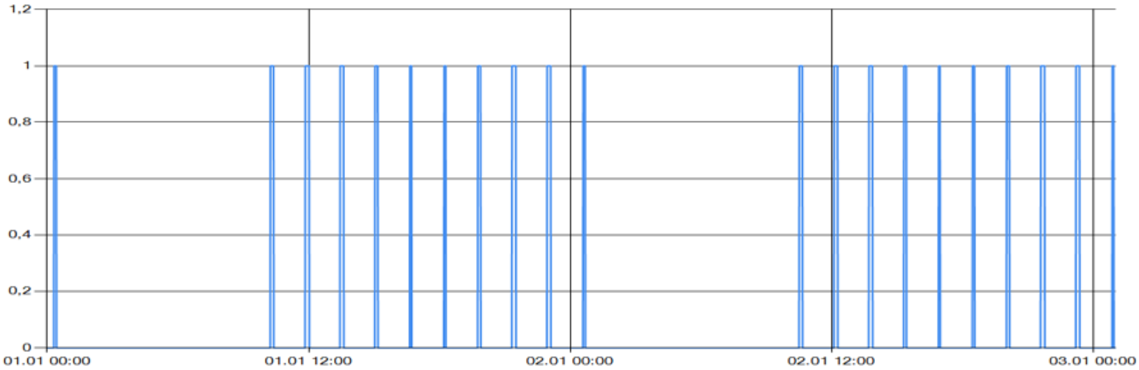

Figure 10 - Periodical coverage of AISSat-1 at Ørland ferry [Source: SINTEF Ocean]

minutes (See Figure 11). However, at lower latitude for example at Ørland (at 63 degrees of latitude), the satellite can only meet a specific area (e.g. Ørland ferry, see Figure 11) on the earth each orbit only in a half of the day. This effect happens because AISSat-1 was developed mainly for managing maritime traffic in the high north regions, especially the traffic around Svalbard. Therefore, if the latitude is not so high, the chance of meeting the satellite will be low and significant longer delay due to waiting time will be counted. In those areas, AIS data and operation can be provided by many commercial AIS satellites (such as Orbicom satellite network). In generally, the more satellites in service the more possibility of providing service and good coverage to the end-users; hence, the higher possibility of detecting AIS messages and forwarding them down to the ground station, minimize the total delay for AIS satellite communications between vessels and ground stations.

Conclusion

A detail comparison between the AIS messages picked up directly by ground stations and AISSat-1 has been conducted for the case with Ørland ferry in Norwegian fjord. With the use of satellite tracking tool, the first finding was about how the ferry, the satellite and the ground station can be positioned: The ground station (at Svalbard) was meeting the satellite in every orbit. The Ørland ferry was covered by the satellite only half of the day, but in every orbit of the AISSat-1 satellite. In the other half of the day, it was outside coverage of the satellite. In those cases where the ferry meets the satellite, the messages were forwarded to the ground station as expected. The message can be transferred from the ferry to the ground station in three different ways: 1) When the satellite covers both the ferry and the ground station at the same time, the message can be forwarded immediately to the ground station. If the ferry has transmitted the message to the satellite, but the satellite is not covering the ground station then: 2) The message is delayed for minutes for the satellite to cover the ground station when it moves south to north; 3) The message is delayed for nearly an orbit for the satellite to meet the ground station again when it was moving north to south. Looking at the ferry, the direction of the satellite will switch between north to south and south to north after a half day, affecting whether the second or the third situation will happen. With big data sets of AIS data, the second finding is that around 30% of the messages were detected by the AISSat-1 satellite compared to the number of messages received by the Brekstad AIS base station. Moreover, due to the feature of an isotropic radiation pattern for VHF band antenna, the rate of messages successfully detected by the satellite is higher at lower inclination angles.

From the investigations done as part of this work, we can conclude that data communication using the AIS-ASM channel can be useful for different kinds of not bandwidth-hungry applications. IALA maintains a collection of existing ASM applications, which covers e-Navigation services, for instance: monitoring aids to navigation, area notices, fairway messages, port reporting services (for dangerous goods, clearance time to port, berthing data etc.), weather data, route data and general messaging of text, among others[‡]. Also, it has been tested the usage of AIS to send general sensor data to support Internet of Things at sea[§] or for ship traffic management in Singapore Strait of Malacca[**]. For logistics services, the most relevant application is for sending and receiving cargo monitoring information and other information related to transport and supply chain.

The next step is to further bring the findings into development of a prototype that integrate AIS/ASM functions and to conduct various measurements of this communication. This will be the main developments for the next phase of the SELIS project when it comes to improving the communication possibilities in difficult conditions.

Acknowledgements

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