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Satellite-based AIS and its Comparison with LRIT

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ABSTRACT: The satellite-based Automatic Identification System (AIS) system has continuously been developed by the shipping industry in recent years. This paper introduces the satellite-based AIS including the concept, the system structure, the development and its new applications. The Long Range Identification and Tracking (LRIT) system, which is mandatory to be required on certain classes of ships engaged on international voyages to report their position at least every six hours using onboard communication means however, has similar kind of function of ship monitoring with the satellite-based AIS system. Based on the basic introduction of the LRIT system, this paper presents the comprehensive comparison between satellite-based AIS and LRIT in terms of the ship's cost, the communication scheme, the monitoring coverage, the information details and the information creditability. The conclusion that the satellite-based AIS should be encouraged to effectively play a complement role to the LRIT system is advanced in the paper.

1 INTRODUCTION

Automatic Identification System (AIS) refers to the technology working on the Very High Frequency (VHF) radio wave that enables the ship's various information such as name, position, type, speed, course, cargo, destination etc. to be automatically exchanged between ship to ship as well as between ship to shore in real time. Since its introduction into the various sectors of the shipping industry, the significant role AIS has played in ensuring the navigational safety, maritime security, marine search and rescue and environmental protection at sea and on shore has been well acknowledged. Nowadays, the utilization of shore-based AIS station network to capture the ship's information transmitted from the onboard AIS equipment in order to track and monitor those ships close to shore has become a standard practice of the vessel monitoring service for the maritime authorities in many nations. However, this so-called shore station-based AIS ship monitoring system is still limited to satisfy the needs of globally identifying the ships due to the limitation of the VHF horizontal range (approximately 20nm and 100nm for onboard AIS equipment and shore-based AIS station, respectively).

In recent years, the serious situation at sea pertaining to the unlawful acts of piracy, armed robbery and port attack by utilizing ships as a weapon has already drawn many costal states to put the long-range or global ship monitoring system on the top agenda in order to effectively track and identify the ships in the wider horizon and at the earlier time even in the real time. As a result, the ship monitoring system combining the AIS powerful information capacity and the satellite global range detection has been prompted and continued in the progress since the beginning of this century.

2 SATELLITE-BASED AIS

2.1 *Concept and system architecture*

The satellite-based AIS, also referred to as the space-based AIS, is created and developed as a global ship surveillance system that uses small low orbit satellites carrying the AIS transponders to receive the ship's AIS information from space and then relay them to the ground station. Consequently similar to other satellite communication and navigation systems, the satellite-based AIS system consists of five components, i.e. small low orbit satellites in space, shipborne AIS equipment, ground station, user and communication link, see Figure 1.

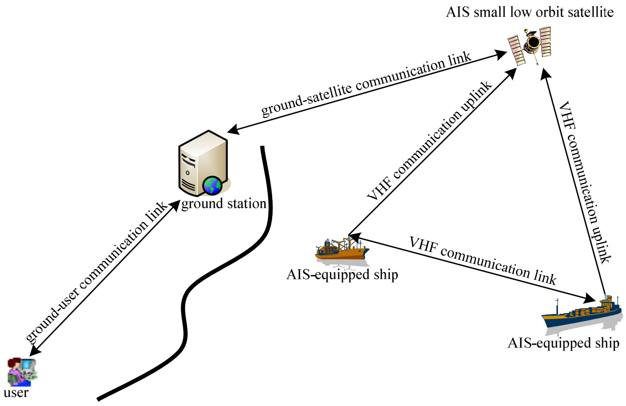

Figure 1. Satellite-based AIS architecture

While the ship's information is automatically exchanged between AIS-equipped ships via VHF communication link, the satellite on which the AIS transponder is installed running on the low earth orbit at the same time is able to receive the VHF signal transmitted for the ship's AIS equipment since the VHF radio wave with the significant signal strength has been proven to be able reach the altitude up to 1000km from the earth ground. The satellite transfers the received VHF signal to the ground station in charge of controlling the whole system. The ground station therefore can distribute the ship's information transferred by the AIS satellite to the authorized user. The communication links between the satellite and the ground as well as between the ground and the user are bi-directional whereas the communication link from the ship to the satellite is uni-directional. Consequently, the satellite-based AIS is capable of globally monitoring the ship's movement in real time if the number of the satellite and the ground station is satisfied. Cain & Meger has shown one of the satellite-based AIS operational results to globally track the ships in the their paper [1].

2.2 *Development*

The concept of satellite-based has continuously attracted Norway, the United States and Canada etc. to make every effort to carry out the relative research with the great investment since its inception in 2003 [2]. The Subcommittee on Radiocommunications and Search and Rescue (COMSAR) of the International Maritime Organization (IMO) made its debut to receive the proposal regarding the satellite-based AIS in 2005. Subsequently, the IMO Maritime Safety Committee (MSC), Navigation (NAV) subcommittee and COMSAR subcommittee have usually remained the space to discuss the satellite-based AIS topic in the various sessions.

In addition, some military units, commercial companies and research institutions have gradually and successfully conducted the satellite-based AIS activities as well as provided the ship's AIS monitoring service based on the satellites.

In 2007, the US Air Force Research Laboratory (AFL) launched the AIS satellite of TacSat-2 in order to verify the concept of the satellite-based AIS for one year [3].

In April 2008, the Space Flight Laboratory (SFL) of Toronto University under the sponsorship of Canadian COM DEV Company has successfully launched the AIS satellite of NTS (Nano-satellite Tracking Ships) after 7-month effort. The exactEarth Company affiliated in the Canadian COM DEV Company has become the first commercial unit for providing the service of satellite-based AIS data in the world [4].

In June 2008, the US ORBCOMM Company and the United States Coast Guard (USCG) jointly launched the AIS satellite of M2M (Machine-to-Machine), but which was out of operation at the end of 2010. In 2011, ORBCOMM successfully launched two AIS satellites manufactured by the LuxSpace Company of Luxemburg. ORBCOMM has planned to 17 AIS satellites by the end of 2014 in order to establish a complete satellite AIS management system, together with the current 16 ground stations [5].

In July 2009, the US SpaceQuest Company launched the two AIS satellites, but both of which were incorporated into the exactEarth Company system since July, 2010[6].

In September 2009, an AIS satellite named as PathFinder2 manufactured by the LuxSpace Company was launched, which enabled this company to become the first commercial unit for providing the service of satellite-based AIS data in Europe [7].

In September 2009, the AIS satellite of SumbandilaSat jointly developed by University of Stellenbosch South Africa, Council for Scientific and Industrial Research (CSIR) and Kenya SunSpace Company has been successfully launched [8].

In October 2010, under the guidance of Norway, the AISSat-1 satellite designed and manufactured jointly by Norwegian Defence Research Establishment (FFI) and Canadian Space Flight Laboratory has been launched. And Norway has decided to launched the AISSat-2 by the 2014 and the more powerful AISSat-3 by the 2015 [9].

In May 2012, Japan Aerospace Exploration Agency (JAXA) has successfully launched the SDS-4 AIS satellite to show the research outcome in aspect of the Satellite-based AIS [10].

In July 2012, the Canadian exactEarth Company has successfully launched the EV-1 AIS satellite, which enabled its satellite-based AIS system of exactView™ to become the largest system for providing the service of satellite-based AIS data in the world [11].

Table 1. Detailed information regarding the AIS satellites

AIS satellite	Launch time	Institute in charge	Weight	Orbital height	Operation status
TacSat-2	2007	US AFL	370kg	410km	out of operation
NTS	2008 .4	Candian COM DEV	8kg	630km	in operation
M2M	2008.7	US ORBCOMM	80kg	775km	in operation
Aprize-3 & 4	2009.7	US SpaceQuest	12kg	565/677km	in operation
PathFinder2	2009.9	Luxemburg LuxSpace	8kg	865km	in operation
SumbandilaSat	2009.9	CSIR, SunSpace	84kg	500km	in operation
AISSat-1	2010.7	Norwegian FFI	6kg	630km	in operation
SDS-4	2012.5	Japanese JAXA	50kg	680km	in operation
EV 1	2012.12	Canadian exactEarth	98kg	817km	in operation
AAUSAT3	2013.2	DMA	0.8kg	800km	in operation

In February 2013, the AIS satellite of AAUSAT3 funded by the Danish Maritime Authority (DMA) but designed by the Aalborg University has been successfully put into service [12].

The detailed information regarding the AIS satellites is summarized in the Table 1.

Furthermore, to meet the rapid development of the Satellite-based AIS service required by the maritime commercial community, the International Telecommunication Union (ITU) have allocated two specific VHF Channels (75 and 76) and defined the new Message 27 for the application of the satellite-based AIS in order to solve the technological difficulty regarding the time slot collision for the shipborne AIS Class A equipment working on the principle of Self-Organized Time Division Multiple Access (SOTDMA) scheme according to the ITU-R M.1371-4 [13]. This new VHF Channels allocation for the marine AIS denotes that the shipborne AIS equipment will be upgraded to support the functionality of transmitting the signals to the satellites in the coming years. It is hence estimated that the service provided by the satellite-based AIS will widely accepted by the industry and make the greater contribution in the ship long-range monitoring in future.

2.3 *New applications*

The initial purpose based on the AIS satellite data is that the shore can track, identify and monitor the AIS-equipped ships in the global for the enhancement of ships safety and security. Many commercial applications have proven that the AIS satellite data has played the essential role in this regard. However, the recent research has demonstrated that the function of the AIS satellite data is more than this. For example, this kind of data is a relatively reliable data sources for assessing the world shipping efficiency [14]; this kind of data is also able to be applied in the analysis of navigational feasibility of the routes in the polar waters [15]. Therefore it is anticipated that the data based upon the Satellite-based AIS will become a basic but most valuable data for the global shipping commercial application and research.

3 LRIT SYSTEM

3.1 *Mandatory requirement*

The Regulation V/19-1 of the International Convention for the Safety of Life at Sea (SOLAS) 1974 effective on January 1 2008 was amended and adopted by the IMO in 2006 mandating that ships engaged on international voyages, including all passenger ships, high speed crafts, cargo ships of 300 gross tonnages and above and mobile offshore drilling units are requested to bear the obligation to automatically transmit the LRIT information including their identity, position and date/time of the position to the Flag States at 6-hourly intervals or upon poll requests for an on-demand position report at the interval to a frequency of a maximum of one every 15 minutes. It is quite obvious that the purpose of LRIT system is of providing the Flag State with the global identification and tracking of ships.

3.2 *System architecture*

The complete LRIT system is comprised of the shipborne LRIT information transmitting equipment, the Communication Service Provider(s), the Application Service Provider(s), the LRIT Data Centre(s), including any related Vessel Monitoring System(s), the LRIT Data Distribution Plan and the International LRIT Data Exchange. The LRIT system architecture is illustrated in the IMO Resolution MSC.263(84) [16].

Each Flag State is required to establish or select a LRIT Data Centre to directly collect the LRIT information transmitted from the ships entitled to fly its flag. The LRIT information is always available to the ship’s Flag State while the Data Distribution Plan developed by the IMO in accordance with the Flag State’s routing rules and connected with the International LRIT Data Exchange provides the scheme to another Flag State for the valid access of the LRIT information of the ships concerned. The Commercial Service Provider and Application Service Provider play the role of enabling the communication between the satellite and the data centre.

It is also acknowledged that “a robust international scheme for LRIT of ships is an important and integral element of maritime security” and “an active and accurate LRIT system also has potential safety benefits, most notably for maritime search and rescue” [17].

4 COMPARISON BETWEEN SATELLITE-BASED AIS AND LRIT

4.1 *Ship's cost*

The shipborne terminal for the satellite-based AIS is undoubtedly of the AIS equipment onboard. There is therefore no additional cost the ship should currently incur to maintain the normal operation of the satellite-based AIS as long as the AIS equipment has already been installed onboard and operated in normal condition. However, if the new AIS equipment to support the new VHF channel allocation for the use of the satellite-base AIS is required in future, the ship should pay extra expense to upgrade the AIS equipment.

For the LRIT shipborne terminal, the technical means are not specified and it can be any communication terminal on board the vessel that is capable of automatically and on receipt of a specific request from the shore transmitting the ship's LRIT information. In practice, the satellite-based communication mean probably existing Global Maritime Distress and Safety System (GMDSS) equipment such as Inmarsat C terminal with the data-polling service and Ship Safety Alert System (SSAS) is widely applied as the LRIT shipborne terminal on the ships engaged on international voyages. Even though the cost of establishing the LRIT system is mainly borne by the Contracting Government, there is still a cost regarding GMDSS equipment upgrading or standalone equipment installation and testing that ships should incur in ensuring the LRIT equipment on board the ship can respond to the LRIT requirements.

4.2 *Communication scheme*

Subject to the communication scheme between the satellite and the ship, the satellite-based AIS is designed as an uni-directional monitoring system while the LRIT system is maintained as a bi-directional monitoring and communication system. An AIS satellite is able to simultaneously capture all AIS information transmitted from the ships within its footprint but it cannot send any signal instruction to any shipborne AIS equipment within its footprint since there is no communication downlink from the satellite to the ship. From this perspective, the satellite-based AIS is definitely a monitoring system.

In contrast, as in most cases the majority of the LRIT shipborne terminals is based on the Inmarsat-satellite mean, each Flag State data center is designated to link to Flag State ship's terminals and vice versa via Inmarsat satellites. In other words, a LRIT ship terminal is able to automatically send information as required to the Flag State data center and the Flag State data center can send signal instruction to a ship because one of most important characteristics for the LRIT system is that the shipborne terminal is able to receive the request instruction transmitted from shore-based data center and make the corresponsive response. The LRIT system is therefore a monitoring and communication system.

4.3 *Monitoring coverage*

As the low-earth-orbit satellites are utilized in the satellite-based AIS, in theory, the satellite-based AIS can globally, including the polar waters, monitor and track the ship's information in real time if the nominal number of the satellites and the ground stations is satisfied. That is why the current satellite-based AIS is able to draw the global ship monitoring picture but still have a little time delay due to too few satellites and ground stations in operation.

As for the LRIT system mainly depending upon the Inmarsat Geostationary Orbit satellites for tracking the ocean-going ships, the monitoring geographical coverage is limited to the range between two latitudes of 76° due to the Inmarsat-satellites nominal footprint. Hence, the LRIT system is unable fully to identify and track the ships sailing beyond the range between two latitudes of 76° such as the polar waters.

4.4 *Information details*

Compared to the LRIT system which only three types of ships' information, i.e. their identity, position and date/time of the position are available, the satellite-based AIS has enjoyed quite rich ship's information available since its received information is directly emanated from the any types of onboard AIS equipment. Taking Class A AIS equipment as an example, this equipment is able to exchange four categories of message, static, dynamic, voyage-related and safety-related including more than 20 types of ship's details. Even for the AIS Message 27, it still includes the ship's identifier, position and its accuracy, navigational status, speed and course etc. More ship's monitoring information is available, more choice is also available for more users to manage ships. Moreover, the theoretical capability of the satellite-based AIS receiving the ship's information in real time is also advantageous to the information refresh interval from 15 minutes to 6 hours of the LRIT system.

4.5 *Information creditability*

The LRIT system is established by the international organization and the Contracting Governments from the beginning in order to enhance the navigational safety, security and marine environmental protection. According to the LRIT performance standard, the LRIT information is provided to Contracting Governments and Search and Rescue services entitled to receive the information, upon request, through a system of National, Regional, Cooperative and International LRIT Data Centers. Therefore, the LRIT information can only be used by the governmental organs for maritime security, safety and marine environmental protection. The confidentiality and sensitivity of the LRIT information are highly stressed by Contracting Governments and not shared with any commercial entities. The LRIT information is of high creditability. However, the satellite-based AIS is launched and developed by some private companies and the ship's information may be widely shared by the commercial users who pay.

5 CONCLUSION

It is obvious that the satellite-based AIS and the LRIT system are developed to provide the service of the ship detection and identification in the long range in order to enhance the maritime safety, security, marine environmental protection and the efficient shipping. However, both also deserve the pros and cons. The satellite-based AIS seems to experience the merits of the ship's global monitoring coverage in theory and the powerful information categories available in contrast to the LRIT system. Nevertheless, the LRIT system is designed as a navigation and communication system and organized by the Contracting Government so that it is able to have a bilateral link between the shore and the ship and enjoy the better information creditability. Additionally, the ship should bear the extra fee to upgrade the current AIS equipment onboard to effectively support the use of the satellite-based AIS. Therefore the satellite-based AIS does not supersede the LRIT system as the LRIT system is more governmental but the satellite-based AIS is focusing on more commercial. And the information provided by the satellite-based AIS is indeed welcome by the industry to promote the efficient shipping, so the satellite-based AIS should be encouraged and developed in order to effectively play a complement role to the LRIT system.

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