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LETTER

The Design of a Total Ship Service Framework Based on a Ship Area Network

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SUMMARY The rapid growth of IT technology has enabled ship navigation and automation systems to gain better functionality and safety. However, they generally have their own proprietary structures and networks, which makes interfacing with and remote access to them difficult. In this paper, we propose a total ship service framework that includes a ship area network to integrate separate system networks with heterogeneity and dynamicity, and a ship-shore communication infrastructure to support a remote monitoring and maintenance service using satellite communications. Finally, we present some ship service systems to demonstrate the applicability of the proposed framework.

key words: *ship navigation and automation systems, ship service framework, ship area network, satellite communications*

1. Introduction

The rapid growth of IT technology has enabled ship navigation and automation systems to gain better functionality and safety, along with reduced costs and crew numbers. The most important systems to be automated on modern ships are the Integrated Bridge System (IBS) for navigation, the Control and Alarm Monitoring System (CAMS) for machinery and cargo, the Bridge Maneuvering System (BMS) for propulsion and the Voyage Data Recorder (VDR). Although these systems were designed and equipped for specific functionalities, they can facilitate a safer and more efficient ship operation by providing integrated information through interconnection. However, they generally have their own proprietary structures and networks, which make interfacing with them difficult. In addition, the remote monitoring and maintenance services for the systems can be key elements affecting customer choices, because a ship may be located in a very remote area. There are some key questions about these limitations, namely how to collect the ship's navigation and automation systems data, how to monitor a ship's data from onshore offices, how to get support from experts while sailing, and how to reduce the maintenance costs. These developing aspects necessitate a backbone network for ship navigation and automation systems and an infrastructure for ship-shore communications.

The International Maritime Organization (IMO) has discussed e-Navigation for safer and more efficient ship operation since 2005. According to the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), e-Navigation is the harmonized creation, collection, integration, exchange, and presentation of maritime information on board and ashore by electronic means in order to enhance berth-to-berth navigation and related services, for safety and security at sea and protection of the marine environment. It is based on not only intra-ship network technology for integrated ship control, such as Maritime Information Technology Standard (MiTS) [1], but also integrated shipboard information technology for 4S (ship-to-shore, shore-to-ship, ship-to-ship and shore-to-shore) communications [2]. However, most of the research and standardization tools that can serve to integrate ship navigation and automation systems and develop a systematic ship-shore communication infrastructure for e-Navigation are in the early stages of development. On the other hand, much research has been proposed for remote monitoring and maintenance services [3], [4]. The operation of these remote monitoring and maintenance systems is typically based on integrated information of the target system(s), qualified analysis methods, and guaranteed access security. Therefore, the remote monitoring and maintenance service of a ship will also require integrated environments capable of collecting a ship's data from each system consistently and accessing each system remotely.

In this paper, we propose a total ship service framework that includes a ship area network to integrate separate system networks with heterogeneity and dynamicity, and a ship-shore communication infrastructure to support the remote monitoring and maintenance services using satellite communications. In Sect. 2, we briefly review the total ship service framework. Next, we give an overview of a ship area network and a ship-shore communication infrastructure. In Sect. 3, we describe some ship service systems based on the proposed framework. In Sect. 4, we discuss the conclusions reached in our study.

2. Total Ship Service Framework

The total ship service framework is divided into a ship area network and a ship-shore communication infrastructure. The ship area network is designed to provide a seamless interface between ship navigation and automation systems through a standardized protocol and an intelligent gateway, which enables two or more systems to be joined by

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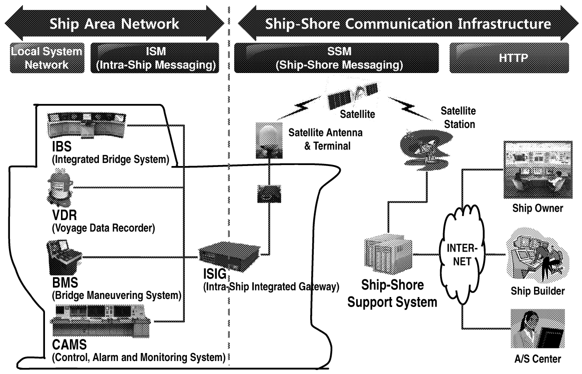

Fig. 1 An overview of the total ship service framework.

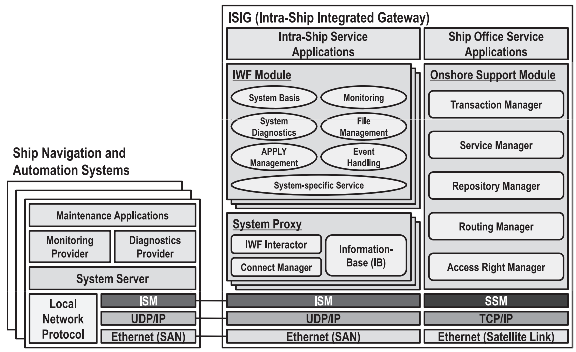

Fig. 2 The architecture of the ship area network.

a single user interface. The ship-shore communication infrastructure focuses on satellite communications and onshore support systems based on Commercial Off-The-Shelf (COTS) technologies for remote ship access. Figure 1 shows an overview of the total ship service framework.

2.1 Ship Area Network

In general, a ship network consists of a ship office network, individual networks for ship navigation and automation systems, and direct connections between them. However, this configuration can only support a partial ship management due to the complexity of the interface between ship navigation and automation systems. To overcome this restriction, we developed the Intra-Ship Integrated Gateway (ISIG), which is an intelligent gateway that allows for: the integration of ship navigation and automation systems, the elimination of direct connections between them, the connection with ship office networks, and the support of ship-shore communications. ISIG is not only a gateway, but also an integrated data center for all ship navigation and automation systems. Ship navigation and automation systems are connected to ISIG and communicate with it directly. Therefore, any system can exchange various types of data with other systems via ISIG, where ISIG forwards the traffic to its destination according to the registered traffic information. In short, ISIG makes a common system network, which we define as a Ship Area Network (SAN). The architecture of SAN is represented in Fig. 2.

The ISIG software was designed for message-oriented system interface, focused on sending and receiving messages [5], and general Application Programming Interfaces (APIs) to reduce the complexity of the developing applications. The message-oriented system interface provides the functionality that supports asynchronous calls between ship navigation and automation systems and ISIG to prevent an incoming message from being blocked by abnormal processing of any previous message, as well as provides an internal queue with the watchdog timer to retry blocked or failed messages when the target system is busy or not connected. ISIG is implemented by a category of inter-application communication software that generally relies on asynchronous message-passing.

Practically speaking, ISIG includes a system proxy and an Inter-Working Function (IWF) module to provide monitoring and diagnostics information for specific ship automation or navigation systems. The system proxy is an agent for connecting ISIG with any system over SAN, which consists of an IWF Interactor, a Connect Manager and an Information-Base (IB). Although it is operated by asynchronous calls of the IWF module, it has some IB-related automation functions to manage the device configuration, to update the periodic runtime data, to detect changes in the device status, and to activate the event messages for the system. The IWF module, which is a group of APIs based on the concept of the message-oriented system interface, is used to maximize the effect of system integration and minimize any extra interfaces with a system. It represents global definitions and general APIs, using a tagging rule for easy access through a unique identification of system devices, and each API of the IWF module includes its callback function in order to support any asynchronous call. The APIs are classified into 7 categories: a system basis class for device configuration and basic information; a system diagnostics class for devices and network status; a monitoring class for periodic runtime data; a file management class for file uploads and downloads; an APPLY management class for database modifications, configuration changes, hardware setting updates, and software upgrades; an event handling class for event subscription and unsubscription; and a system-specific service class for system-specific raw data and historical data services.

An onshore support module for ISIG facilitates the development, maintenance, and execution of remote ship service applications that are the fundamental software used to provide value-added services in onshore offices. This module consists of a Transaction Manager, a Service Manager, a Repository Manager, a Routing Manager, and an Access Right Manager. The Transaction Manager is the key component of an onshore support module and is responsible for managing messages until it completes their processing and returns the results to a message-initiator. To accomplish this, each message contains the target system ID, the transaction ID, and a data payload to be passed as arguments. The Service Manager analyzes a message to determine if it should be processed in ISIG or sent to a target system and then returns the results from the Repository Manager or a target system, depending on its properties. The Repository Manager manages a database to store the core information for each system and ISIG itself, which is typically static or updated periodically. The Routing Manager is an object which controls the interaction with each system's IWF module to pass a message to a target system. Finally, the Access Right Manager guarantees secure access based on the user account and authority.

SAN provides, in addition to the inter-operability of systems, a unified communication path from the outside world via ISIG to make value-added ship services possible. It is based on the Ethernet used widely in local area networks, which was standardized as IEEE 802.3 and can support high-speed and mass-data communication against other serial communication technologies. To efficiently support the total ship management, it is necessary that the standard communication protocol is applied to various communication devices in ship navigation and automation systems. Therefore, we developed an Intra-Ship Message (ISM) protocol that was designed for communication with ship navigation and automation systems. It is based on the earlier version of the IEC 61162-450, which is known as Light-Weight Ethernet and has been on the standardization work for digital interfaces of maritime navigation and radiocommunication equipment and systems. Note that advanced secure functions for communications should be implemented at the application layer because ISM protocol is the transport layer protocol based on UDP (User Datagram Protocol) port numbers.

ISM protocol supports three types of communication data: simple and periodic data types, binary data types, and file data types. Firstly, a simple and periodic data type includes unreliable data traffic, such as sensor data represented by NMEA sentences. Because the traffic in this type of message occurs periodically, it can be transmitted without a control message or feedback for guaranteeing the delivery of the message to the receiver. Secondly, a binary data type includes reliable data traffic for diagnostics and maintenance. For reliable data transmission, this type of message requires the exchange of an extra control message, such as ACK or QUERY. Finally, a file data type that includes historical data files, navigation images and audio files, maintenance files, and various system files, is a special case of a binary data type. These require not only the exchange of extra control messages for reliable communication, but also file transfer mechanisms for the safe transfer of bulk messages. In addition, traffic of this type includes the exchange of file-related information.

2.2 Ship-Shore Communication Infrastructure

The ship-shore communication infrastructure consists of ISIG, satellite communication devices, and an onshore support system, as shown in Fig. 3. As described in the previous

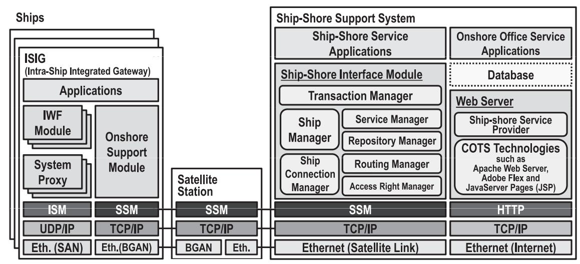

Fig. 3 The ship-shore communication infrastructure.

section, ISIG is a core device communicating with an onshore support system to provide ship-related services, such as the monitoring and diagnostics of ship navigation and automation systems. The data exchange between ISIG and the onshore support system is made possible through satellite communications, because a ship navigates at sea. Therefore, satellite communication devices are equipped with ISIG in a ship.

In the paper, we considered Inmarsat FleetBroadband for satellite communications, which has delivered innovative, reliable, and cost-effective communication solutions to the maritime industry. It supports secure high-speed IP communications and provides fully integrated satellite communication services incorporating voice and data applications through the Broadband Global Area Network (BGAN). Its antenna and below-deck equipment package are suitable for onboard installation and offer a comprehensive array of features and benefits.

In addition, we developed a Ship-Shore Message (SSM) protocol that was designed specifically for satellite communications between a ship and an onshore support system. SSM protocol is a reliable, secure, and efficient messaging protocol based on the TCP (Transmission Control Protocol) and the proprietary data structures compressed by a bzip library. Furthermore, it supports multiple ship connection management using pre-shared keys for encryption and decryption and providing two-channel communication for non-blocking.

The structure of the onshore support system is similar to that of the ISIG onshore support module, except that it interacts with multiple ships, not just the ship navigation and automation systems, and provides a multi-user environment. To support this feature, the ship-shore interface module of the onshore support system must have two additional objects: a Ship Manager and a Ship Connection Manager. The Ship Manager manages the basic ship information, such as ship's name and location, and Ship Connection Manager supports the actual communication with a specific ship. In addition, it includes a Web Server linked to the ship-shore interface module to allows user access from anywhere with a standard web browser, providing a user-friendly interface.

3. Implementation of Ship Service Systems

In this section, we discuss which ship service systems were applied using the proposed framework. To begin with, we

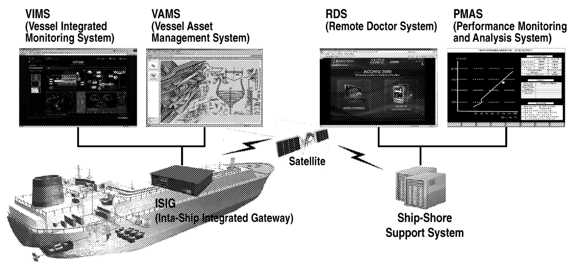

Fig. 4 The summary of ship service systems.

classified ship service systems into intra-ship service systems and ship-shore service systems, according to their service locations (Fig. 4).

As intra-ship service systems, we propose the Vessel Integrated Monitoring System (VIMS) and the Vessel Asset Management System (VAMS). VIMS provides monitoring information of ship navigation and automation systems wherever ISIG is accessible. The VIMS server is installed in ISIG and cooperates with the IWF module, where runtime data, such as sensor data, is collected by the APIs of the monitoring class, and historical mass data, such as alarm lists and trends data, is obtained by the APIs of file management class. The implementation of VIMS can generate a 'single-window' operator interface for a one-man bridge because of its fully-integrated monitoring and control functionality. VAMS was designed for the efficient management of an onboard crew, devices, and facilities. It includes supply, maintenance, purchase and stock management, as well as crew management. It is also equipped in ISIG and collects maintenance information using the IWF module.

In terms of ship-shore service systems, we suggest the Remote Doctor System (RDS) and the Performance Monitoring and Analysis System (PMAS). RDS is a remote monitoring and diagnostics system which provides expert knowledge in onshore offices. It has monitoring functions for the general conditions of a ship's equipment and maintenance support functions, including system diagnostics, system health checking, troubleshooting, and software upgrades. Therefore, it can be used to reduce maintenance costs by cutting travel costs and wasted time for specialists. This is accomplished through interaction between SAN and a ship-shore communication infrastructure by an onshore support module of ISIG. PMAS is an integrated condition monitoring system that supports the performance, optimization and health monitoring for the efficient voyage and extended life cycle of a ship. Because PMAS is based on performance data historically collected from the ship navigation and automation systems, it can be implemented by an onshore support module associated with the APIs of the file management class of the IWF module in ISIG.

4. Conclusion

In this paper, we proposed a total ship service framework that includes a ship area network and a ship-shore communication infrastructure. For the construction of the total ship service framework, we developed ISIG, which is not only the gateway but also the integrated data center, in a ship. In addition, we applied ISM protocol to a ship area network and SSM protocol to satellite communications as standardized protocols. Finally, we presented some ship service systems, such as VIMS, VAMS, RDS, and PMAS, based on the proposed framework. In the next phase of our study, we will evaluate the impact of the ship service framework in real environments.

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