Backbone Network Architecture Planning of Ship Area Network

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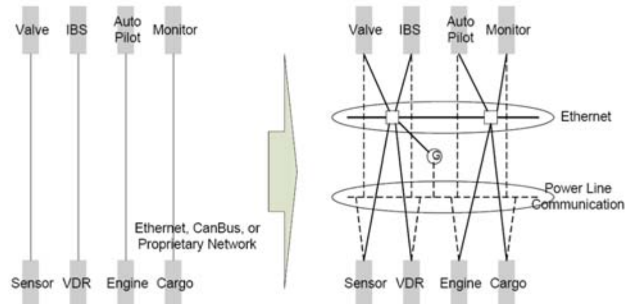
***Abstract* — This paper presents the backbone network architecture model to reduce capital expenditure and operation expenditure in the SAN. This paper considers the traffic models and the limitations on the SAN to design the network architecture. This paper also evaluates the designed SAN using a simulator and suggests the type and the minimum performance requirements of network element for inter-connecting devices in the SAN. The performance evaluation results show that the grouped devices and a Ethernet switch which has the switching performance over than 30,000 packets/s can provide very low packet loss and very short packet delay to the devices connected on the SAN.**



(a) Conventional SAN (b) SAN with backbone

Fig. 1 Architecture of conventional SAN and SAN with backbone architecture

I. Introduction

The ship area network (SAN) is the network in a ship, which provides the connection between the control, monitoring devices in the ship area. The SAN is the one of important parts in the ship automation because the network deals with status and control information of devices in the ship. Therefore, the ship automation is impossible without the SAN, and in that case, the large ships such as container ships or battle ships should require the many crews to control the ship during the voyage.

The isolated network offers low packet loss ratio and short packet delay because the network does not suffer from the influences of traffics from other networks. So the current network architecture of SAN is organized as the isolated networks as shown in the Figure 1.(a). However, the isolated network causes more capital expenditure(CAPEX) and operation expenditure(OPEX) than backbone network because the long distance of cable in the isolated network causes high cost in the cable installation and the maintenance[1]. Therefore, the shipbuilder or international organization relating to the ship such as the international maritime organization (IMO) or the international electrotechnical commission (IEC) tends to organize current ship area network to a single network with backbone architecture as shown in Figure 1.(b). By these reasons, this paper focus to design the backbone network architecture of the SAN.

There exist several groups related to the shipbuilding and voyage of the ships, but two groups have major influence on the backbone architecture planning of SAN. One is the international organizations such as IMO and IEC, which define the standards for the structure of the ship and the regulations on the voyage. The other is the ship-owners and shipbuilders, which use and build the ship, respectively. The two groups have a tendency to do cautious in the changing architecture of ship because unconfirmed architecture of network may cause malfunctions or errors on devices during a voyage. These malfunctions and errors result in the large amount of expenditure on repairing the devices. Therefore, to confirm and show the confidence and the robustness of the designed network, and to reduce the cost for the deployment of network, the simulator for the performance evaluation of SAN must be developed.

This paper presents the designs of SAN with backbone architecture and shows the evaluation results of that network by using the simulator for SAN. Chapter 2 describes about the conventional ship area network and Chapter 3 presents the traffic model and design of SAN with backbone architecture. Chapter 4 shows the performance evaluation of designed network. Finally, the conclusion will be followed.

II. Conventional Ship Area Network

The form of current network architecture of SAN is isolated network as shown in Figure 1.(a) because the isolation of networks prevents the performance degradation such as packet loss or delay by the traffics of other networks. In this architecture, the networks in the ship become isolated because the networks are organized by the direct connection between each groups.

However, the requests of many communication lines cause high cost in the cable installation and in the maintenance although the design of network becomes simpler by the direct connection between each groups. Also, the isolated network does not allow the integrated network management, so multiple devices are needed for controlling and managing the other devices in the ship. Therefore, the international organizations, shipbuilders and ship-owners are trying to replace this old-style wiring with a modern

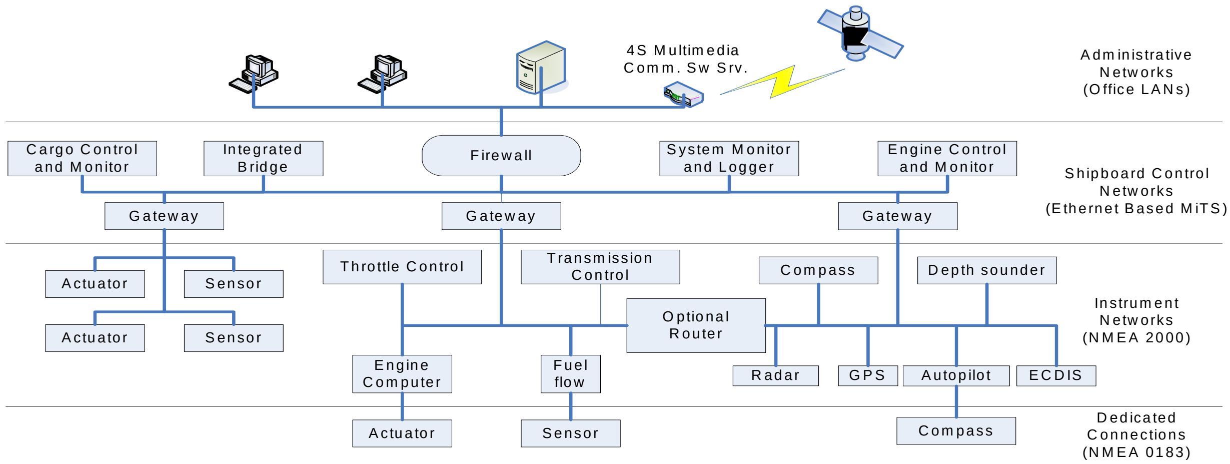


Fig. 2 Architecture of SAN with backbone architecture

backbone network as shown in Figure 1.(b).

III. Design of SAN with Backbone Architecture

A. *Traffic Model of the Ship Area Network*

For the acceleration, control, status monitoring, and the communication with the nodes in outside of ship, many devices are installed in the ship. The number of devices in the SAN of a general container ship is almost 460 and these devices are connected by isolated networks. These devices are connected to the ship area network and transmit traffics through the network. Figure 2 represents an example of SAN with backbone architecture with functional division [2].

The traffics in the SAN are must be lossless and not be delayed too much because most of traffics carry control and status information in the ship. Fortunately, most of traffics from devices in the ship are ignorable in the evaluation of network performance because these traffics have very small packet size and very low transmission frequency. However, some traffic is not ignorable because their packet size is not small and transmission frequency is high. Therefore, in the evaluation of the network performance, these traffics should be considered. The devices which generate not ignorable traffics and the receivers of those traffics are represented in the below[3]:

Table 1. Traffic model of SAN for the commercial container ship(Model 1)

Source	Destination	Protocol	Traffic
AMS	VDR	UDP	272 kbits per 1sec
AMS	Web Server	UDP	272 kbits per 1sec
VDR	Web Server	TCP	20 kbits per 1sec
VDR	Web Server	TCP	8 Mbits per 15sec

Table 2. Traffic model of SAN from IEC TC 80(Model 2)

Source	Transmission Frequency (message per second)	Message Size (bytes)	Number of devices
GPS	1	79~200	2~15
AIS	50	79~	2~15
INS	50	79	2~15
Gauge NN1	1	79	5~15
PC	1	79	5~15
VDR	1	79	5~15

■ Alarm Monitoring System(AMS) : The AMS collects and shows the status of engine.

■ Integrated Bridge System(IBS) : A combination of systems which are interconnected in order to allow centralized access to sensor information or command/control from workstations, with the aim of increasing safe and efficient ship's management by suitably qualified personnel. It contains a integrated navigation system(INS).

■ Voyage Data Recorder(VDR) : The VDR collects every information during sailing same as black box in the airplane.

■ Global Positioning System(GPS) : The GPS gets the position of the ship from GPS satellite.

■ Automatic Identification System(AIS) : A short range coastal tracking system used on ships and by Vessel Traffic Services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships and VTS stations.

■ Gauge NN1 : The device for measuring balance of the ship.

■ Web Server, Personal Computer(PC) : The server for web-browsing of the information from status of devices in the ship. Crews can use the personally assigned PC to browse the web page in the web server.

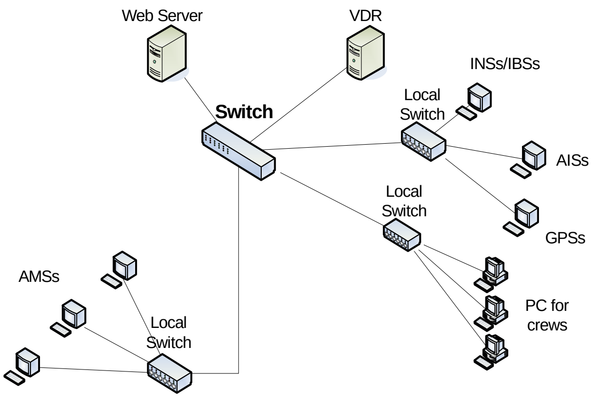


Fig. 3 The designed network of SAN with backbone architecture

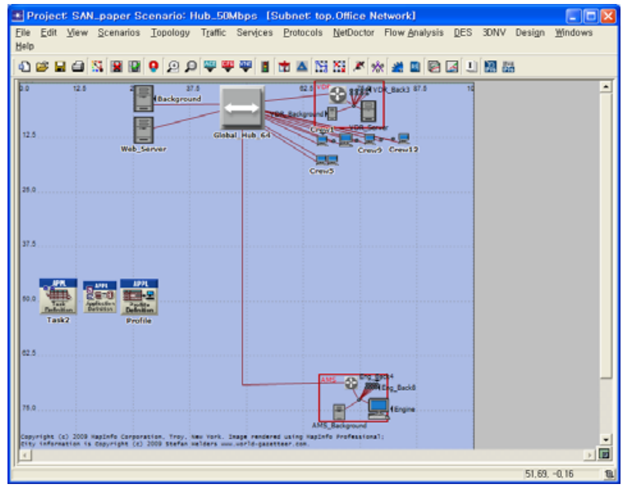


Fig. 4 The simulator for evaluating designed SAN with backbone architecture

B. Network Architecture Design

There are three issues to be considered to design backbone network in SAN. First one is the grouping of devices to limit the connection between a group and a concentrating network element (CNE) and to decrease the distance of cable connection. If the devices are not grouped, then the installation and maintenance cost will increase.

Second is the selection of the number and the type of a CNE which is a device provides the connections between each groups. The grouping reduces the number of connections between the CNE and the groups, therefore single CNE can cover the entire network. However, if the type of CNE is selected not properly then confidence and robustness of the entire network cannot be ensured. Therefore, the selection of the appropriate CNE is one of important network design issues.

Third is the minimum performance requirement of a CNE. If the performance of a CNE is too low then overflow in the network can be occurred. However, the usage of higher capacity CNE will cause the unnecessary cost waste. Therefore, the minimum performance must be evaluated to reduce the cost for deployment of SAN. The minimum performance of a CNE can be expected by the simulation with change of performance of the CNE.

This paper suggests the backbone network models in SAN considering above three issues. The designed network architecture of SAN with backbone architecture is represented in Figure 3. We organized the groups by the objective and the installed area of devices. These grouped devices are connected to a hub then the hub is connected to the CNE. This design decreases the distance of cable connection and the number of ports in the CNE. The switch can be a network element as the CNE because the number of port is sufficient and has low influence from the background traffics. The router is excluded as the CNE in the simulation because the router has small number of ports therefore a single router cannot connect the all devices in the ship. The hub is also excluded because broadcasting nature of hub causes packet loss of UDP traffics and long delay of TCP traffics due to packet collision in the Ethernet link. The switch's minimal performance is 30,000 packets/s because delay converges without any packet loss in that point as shown in the next chapter.

Additionally, for the redundancy of the network, redundant network is considered using another Ethernet link or power line communication as shown in the Figure 1.(b). The redundant network backups the SAN by switched on automatically when primary network has stopped by the error or malfunction during operation(1+1 duplication). However, in this paper, redundant network is not represented in the picture because the connection and position of devices in the network are same with primary network.

IV. Performance Analysis of Integrated Ship Area Network

In this paper, to analyze the performance of designed ship area network, we implemented the SAN simulator using the OPNET 14.5, as shown in Figure 4. We considered the location of each devices in the ship as same as actual places in the container ship. Also, we assumed that the CNE can be one of hub, switch, or router. Each device is connected with 100Mbps Ethernet links since it is enough to support traffic assumptions.

In the simulation, we made two scenarios for checking two topics in the designing of SAN with backbone architecture. Also, we assumed another scenario to check the necessity of the routers between groups and a CNE. In the each scenario, the end-to-end packet losses and delays are measured for the performance index. For considering the worst case, all traffics in the network is 'synchronized' – the starts of all traffics are same therefore the traffic is concentrated on the start of period.

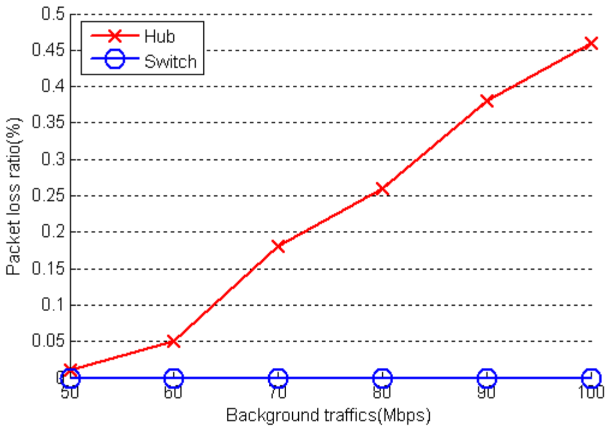


Fig. 5 The end-to-end packet loss of AMS-Web Server traffic of Model 1

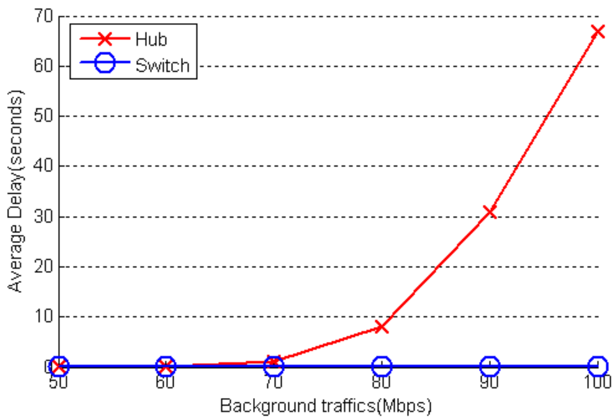


Fig. 6 The average end-to-end one-way delay of VDR-Web Server traffic of Model 1

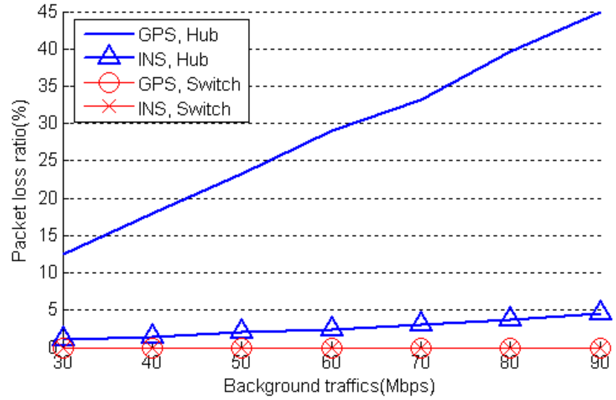


Fig. 7 The end-to-end packet loss of GPS and INS traffics of Model 2 with respects to the background traffics

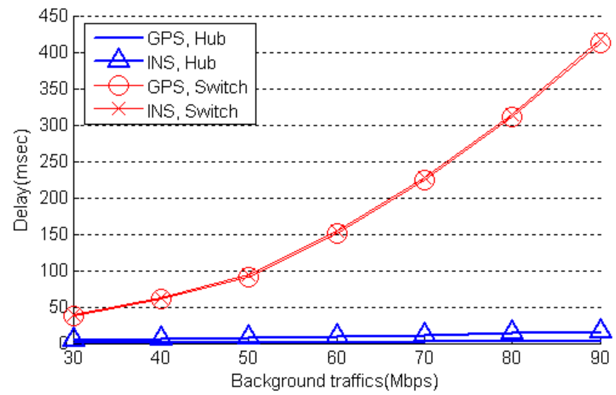


Fig. 8 The average end-to-end one-way delay of GPS and INS traffics of Model 2 with respects to the background traffics

A. Selection of Concentrating Network Element

In this section, the confidence and the robustness of the network are compared when a hub and a switch are used as the CNEs. Figure 5 and Figure 6 shows the end-to-end packet loss of traffic transmitted from the AMS to the Web Server and the average end-to-end one-way delay of traffic transmitted from the VDR to the Web Server according to the background traffics in the network, respectively. Also, Figure 7 and Figure 8 shows the end-to-end packet loss and average end-to-end one-way delay of some traffics in model 2 with respects to the background traffics in the network, respectively. By these results, we can expect that hub is not a appropriate network element as CNE because it causes the end-to-end packet loss when application uses the UDP and increasing of the average end-to-end one-way delay when application uses the TCP. Therefore, we concluded that the appropriate CNE in the SAN with backbone is the switch.

B. Router Placement in the Network

If the SAN with backbone network architecture uses grouping, there is the 'local network traffic'. The local network traffic means the traffic transmitted to the destination within the same group. The traffic load may be increased at a CNE connecting with hubs in SAN due to the broadcasted local network traffic by the connected hubs. It also may cause the queue at the CNE to overflow. So, we evaluated the effects caused by the local network traffic to determine whether to install additional routers.

Figure 9 shows the average end-to-end one-way delay of the traffic transmitted from the AMS to the Web Server according to the packet switching rate of the central switch. The traffic is generated by the model 1 described at table 1. In the result, if the packet switching capability of switch is larger than 30,000 packets/s, then the additional load caused by the connected hubs does not cause the overflow in the network. Also, the routers cause additional delay due to the queueing delay in the routers. Therefore, the network does not need the router for the protection from performance degradation due to local traffic if the CNE has enough performance larger than 30,000 packets/s.

C. Minimum Performance of CNE

In this section, we evaluate the minimum performance requirement of CNE to reduce the cost for the CNE. Figure 10 shows the average end-to-end one-way delay of GPS and

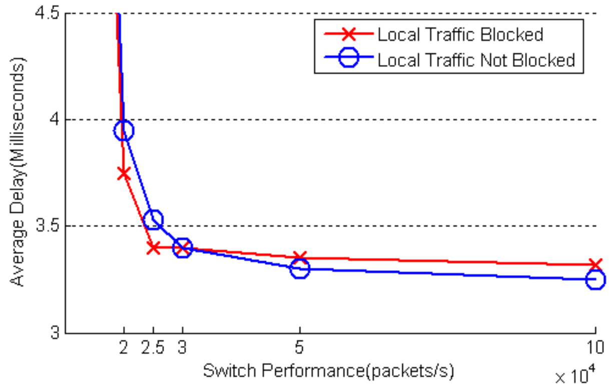


Fig. 9 The average end-to-end one-way delay of AMS-Web Server traffics of Model 1 with respects to the switch performance

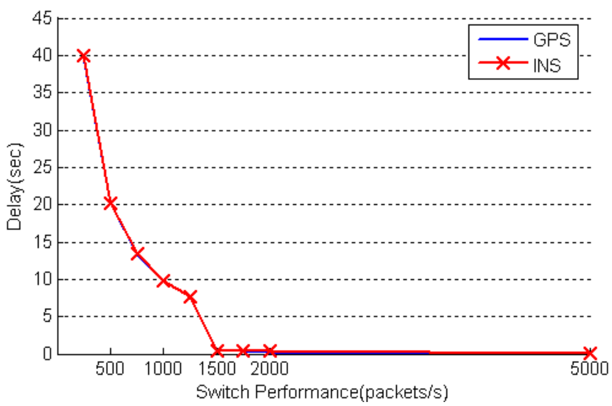


Fig. 10 The average end-to-end one-way delay of GPS and INS traffics of Model 2 with respects to the switch performance

INS traffics of model 2 with respects to the switch performance, and Figure 11 shows the end-to-end packet loss of traffic from GPS and INS in the model 2 with respects to the switch performance. The application delay converges when the switch performance is 30,000 packets/s or more as shown in the Figure 9, while 1,500 packets/s or more as shown in the Figure 10. Also, the packet loss does not occurred when switch has each performance. For example, in the model 2, the packet loss does not occur when switch has the performance of 1,500 packet/s or more as shown in the Figure 11. From the results, we can expect that the switch performance must be larger than 30,000 packets/s.

V. Conclusion

This paper presents the backbone network architecture for the SAN and shows the performance evaluation results of that architecture. This paper also suggests the type and minimum requirement of network elements in the designed architecture. These results can be a reference to minimize the cost for the deployment of SAN with backbone network architecture.

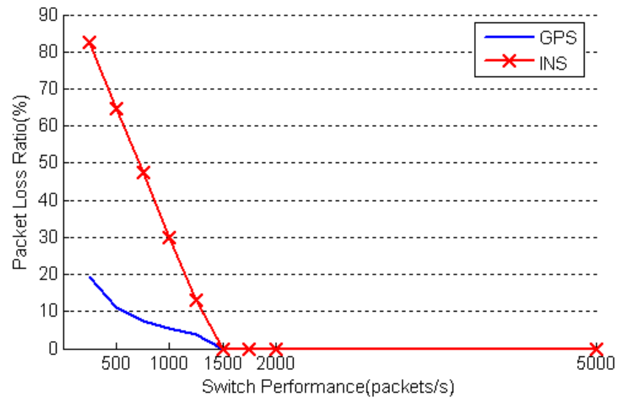


Fig. 11 The end-to-end packet loss of GPS and INS traffics of Model 2 with respects to the switch performance

Summarized results are described below:

- The ship area network can be organized with single CNE. The local switch can be placed in order to reduce the length of link additionally, or provide connectivity between each device. We recommend that the network use a switch as the CNE.
- The minimum performance switch as the CNE must be larger than 30,000 to provide connectivity without packet loss and large delay.

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References

[1] A resentation at the Institute of Navigation, 2002 National Technical Meeting, January 30, 2002.

[2] International Maritime Organization, available at http://www.imo.org/Safety/mainframe.asp?topic_id=59

[3] Lammie, T., “Cisco Certified Network Associate Study Guide,” Sybex, March, 2007.

[4] “Cisco Catalyst Switch Guide,” Cisco, 2009.

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S15-2 A Low-Complexity Step-by-Step Decoding Algorithm for Reed-Solomon Codes
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