Application of Ubiquitous Technology to Ship Environment

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ABSTRACT

Many new technologies from different area are employed in enhancing the safety of ships. This paper proposes using recent ubiquitous technology in order to enhance ship safety. Ubiquitous technology can also provide valuable addition to the ship's service as well as high quality of life to crews and passengers. In this paper, Zigbee communication performance in ship environment is tested in resembling environment and under ship operation condition. Based on the performance of Zigbee communication, a sensor network configuration using Zigbee and PLC (Power Line Communication) is proposed and tested during ship operation. Two application of ubiquitous technology to ship is introduced as well.

1. INTRODUCTION

Ubiquitous technologies such as RFID and USN have succeeded remarkably and are used habitually on land in application areas such as physical distribution management, home network, mobile FRID, U-Health, and U-defense. Because of these technologies, people are able to use a lot of information easily.

However, applying ubiquitous technology on land to ship has major challenges. A ship has very harsh environments to operate in. A ship is essentially a big structure made of steel. The main engine inside the ship transfers significant power to propeller through long shaft for the propulsion of ship. As the deck-house, indicating a superstructure on the upper deck of a ship, is located above the main engine room, equipments inside the deckhouse have to suffer the vibration and noises induced by the propeller or main engine. Most of all, the ship motion such as pitching, rolling and heaving can have adverse effects on the equipments onboard a ship. To apply the ubiquitous technology into ships, these operational environments should be taken account of.

In this paper, considering these characteristics of ship and its operational environment, first, wireless communication experiments are carried out in ship resembling steel structures. Then Zigbee system performance is tested inside a ship. From using Zigbee and PLC is implemented inside the ship and tested under ship operation condition. This paper also proposes two possible application of ubiquitous technology to ship, which are being developed and tested.

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2. Experimental Results

2.1 Testbed Experiment

Our experience during deployment of sensors and routers inside containers shows that while communication inside steel structures is possible with some multi-pass interference and wireless communication between containers (inter-container communication) is almost impossible, even between containers that have windows. Therefore it will be impossible for wireless communication to pass through watertight bulkheads.

2.1.1 Steel Plate Pass Through Test

For steel plate pass through test, Zigbee wireless transmitter is placed at the center of a steel box, composed of 1.6mm steel plate that are welded together. Then three types of steel cover is placed on the one side and screwed tight so that the box is completely enclosed. Then wireless receiver is placed outside the box and transmission success rate is measured. The type of steel cover is selected from typical steel plate used inside a ship.

The test results are shown in Table 1. As expected, 1.6mm and 1mm steel plate did not allow any wireless communication to pass through. However, 0.4mm galvanized steel plate, which is commonly used as room division material inside a ship did pass through some of the wireless signal, which gives some hope for wireless communication between rooms.

Table 1. Steel plate pass through test results

Plate Type	Success Rate	Remark
1.6mm Steel Plate	0 %	Common plate thickness in ship
1 mm Steel Plate	0 %	
0.4mm Galvanized Steel Plate	40 %	Commonly used as room division

2.1.2 Communication Range Test

In order to compare wireless communication range inside ship, first, communication range is measured in open field.

In football field test, RSSI(Received Signal Strength Indication) and success rate is measured to find out the maximum communication range in open field. Figure 1 shows football field test results. Success rate stays near 100% up to about 70m, and drops to 0 at about 105m.

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In tennis court test, the main focus was on the influence of height, where sensor is placed. The test result is shown in Figure 2. T he sensor placed at 0.2m above ground shows much small RSSI than the sensor placed at 1.5m above ground. Using football field test results, the maximum communication range for sensors placed at 1.5m above ground is about 70m, whereas for sensor placed at 0.2m above ground, about 30m.

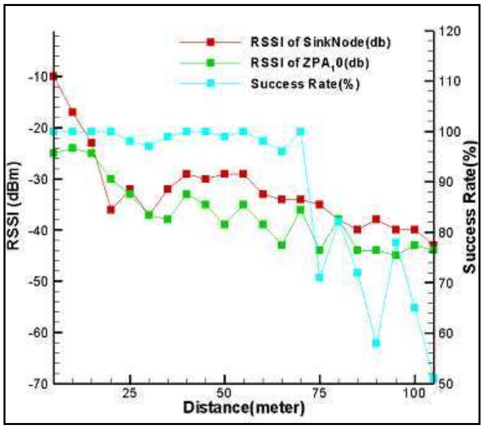

Figure 1. Communication range test in football field

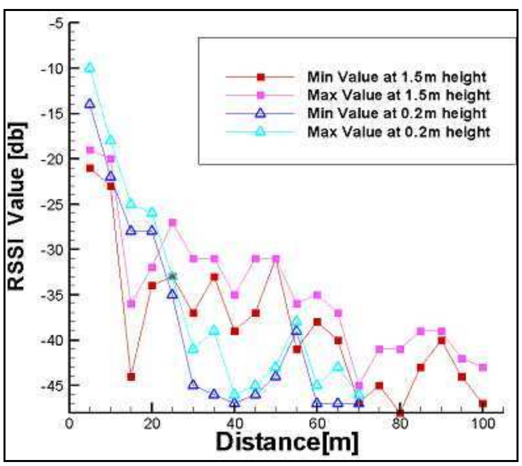

Figure 2. Communication range test in tennis court

2.1.3 Diffraction Test

The purpose of diffraction test is to measure how well wireless signals can bend around steel obstructions. The test was carried out around testbed as shown in Figure 3. The sink node is place at the marked position in the figure, and the transmitter is placed at various points (P1-P11) around a steel container.

Figure 4 shows the test results. RSSI value at all points are above -45dBm, meaning wireless communication is possible. The reason that RSSI values at some points are higher than nearby points is due to signal reflection from the outside of the container.

2.2 Experiment during Ship Operation

Ship experiment was carried out in order to evaluate the applicability of wireless sensor network onboard ship. First, communication range was measured inside the longest corridor and compared with experimental results from testbed experiment. Then communication quality in the major areas inside the ship was measured to give guidance on how to deploy sensor network. Finally, sensor network was deployed in the selected compartment of the test ship and wireless communication was monitored during actual ship operation. Communication range and quality tests were carried out while the ship was docked.

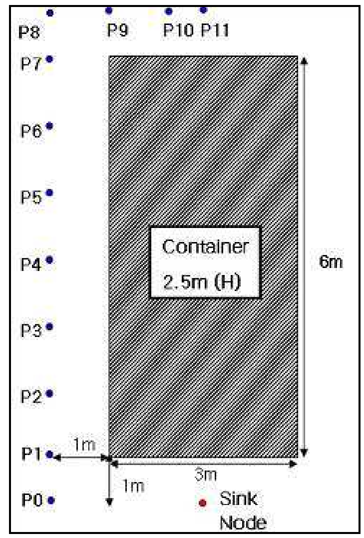

Figure 3. Diffraction test setup

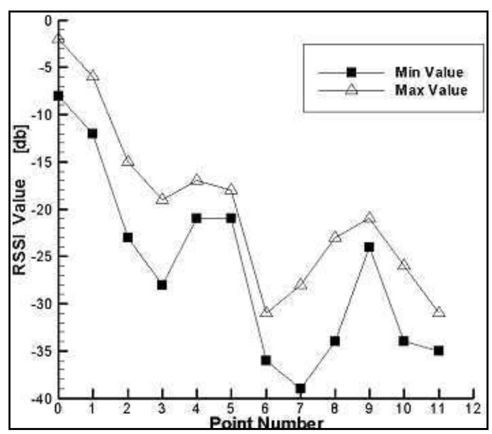

Figure 4. Diffraction test results

2.2.1 Communication Range Test

Communication range test was carried out inside the longest corridor of the ship in the same way as open field test described in previous section. Figure 5 shows the result of communication range test. Test results show that while RSSI in the test ship is

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generally higher than in case of open field test, success rate is lower. This due to the fact that reflections from narrow corridor contribute to the general signal strength, but these reflections can cause interference which lowers success rate. However, the results also indicate that wireless communication promising inside steel structures, as long as there are no obstructions between two points of communication. The case where there are obstructions is investigated in communication quality test.

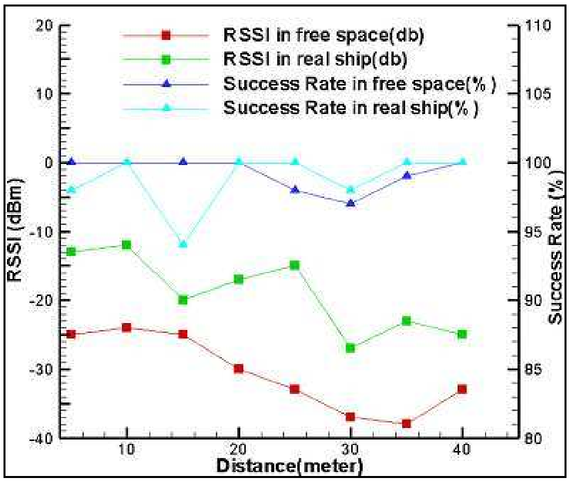

Figure 5. Communication range test results

2.2.2 Communication Quality Test

Communication quality tests arsde carried out to evaluate wireless communication inside the test ship where there are obstructions between two points of communications. The results are summarized in Table 2. Wireless communication inside the ship shows quite promising results, as long as there is no watertight bulkhead between two points of communication, which are in accordance with previous diffraction test results.

Table 2. Communication quality test results

Obstruction	Distance (m)	RSSI (dBm)	Success Rate (%)
Cabin door	1	-27 ~ -30	98 ~ 100
Stairs	3	-10	100
	4	-18	100
	5	-14	100
Deck	3	-46	63
Bulkhead	2	-	0

2.2.3 Wireless Sensor Network Deployment

Based on the communication quality test results, sensor network was deployed in 4 typical compartments inside the test ship; bosun restaurant, restaurant, cabin and main engine room. For communication inside each compartment, Zigbee wireless communication protocol is used and for communication between compartments, PLC is used since wireless communication is impossible between watertight bulkheads. Figure 6 shows how sensor network was deployed.

2.2.4 Test during Ship Operation

During 48 hour voyage between Busan and Cheju Island, wireless communication is monitored at two place; control room in main engine room and wheelhouse. Table 3 summarized success rate for sensors deployed in main engine room and bosun restaurant.

Wireless communication inside a ship shows very favorable results. All success rates were above 75%. The reason why PLC success rate is lower than Zigbee is because there are some packet losses in Zigbee-PLC module as shown in PLC/Zigbee success rate.

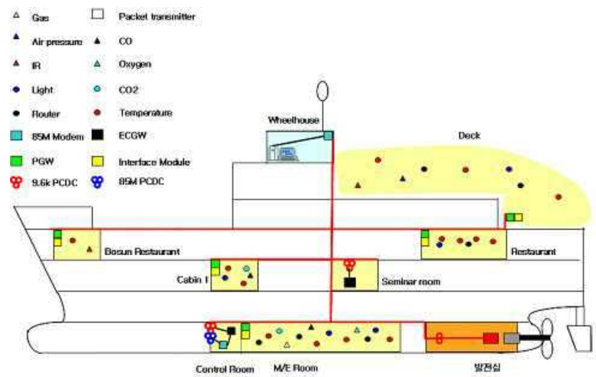

Figure 6. Deployment of sensors inside the test ship

Table 3. Test results during ship operation

Area	Node	Zigbee	PLC	PLC/Zigbee
Main Engine	Router	87.87	86.21	98.12
	Router	86.21	84.11	97.56
	Temperature 1	88.67	82.16	92.66
	Router	90.98	86.07	94.59
	Light	93.58	88.31	94.36
	CO	88.88	82.81	93.17
	Gas	89.68	85.84	95.72
	Temperature 2	89.75	85.49	95.24
	CO_2	87.87	75.37	85.77
Bosun Restaurant	Router	97.31	92.67	95.24
	Light	96.95	90.49	93.36
	Temperature 1	98.25	92.43	94.11
	Temperature 2	97.67	92.52	94.74
	Light	97.51	91.56	93.77

3. Application of Ubiquitous Technology to Ships

The area where ubiquitous technology is applicable to ship are investigated and conceptual service scenarios of those applications are developed in the present study. The results of the study in the paper may be used as a basis for full-scale application of ubiquitous technology to ships in the future.

3.1 Planned Maintenance System

A ship has many types of equipment onboard and since pumps or motors in main engine room are closely related to the supply or discharge of cooling water, failure or abnormal operation of

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these can cause serious troubles in ship operation. The current method for the transmission of data is mostly through wired communication network. It means that higher cost of cabling and complicated networks is necessary in order to sense more equipment. Therefore, many ships have monitoring system for only essential equipments. However, ubiquitous technology can make it possible to monitor much more equipments while reducing the necessary cost.

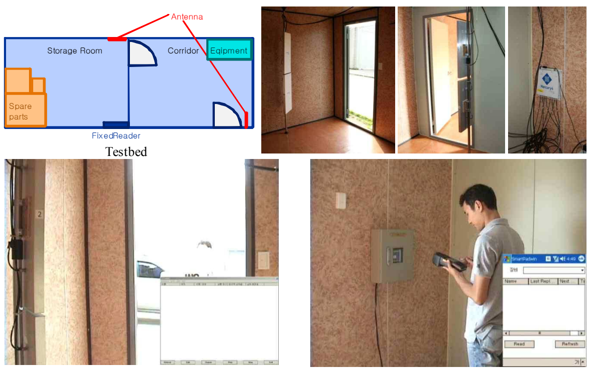

Figure 7. Experimenting PMS system in Testbed

3.2 Fire Prevention System

It is not easy to ask for external help for putting out a fire in a ship because ship spends most of time on the sea and much time is needed for other rescue ships to arrive. Therefore, preventing fire in advance by assessing its possibility during operation is very important. Current practice is to notify crews and passengers by alarm when a fire is detected based on temperature or smoke and then fire suppression systems are operated either automatically or manually.

The operation of fire suppression systems after the break out of fire may result in unavoidable damages, no matter how fast the fire is extinguished. Sometimes environmental condition of a specific fire zone hinders proper suppression of fire and result in large scale fire. It is much better to prevent fire by assessing the possibility of fire before it actually occurs. However, it was very difficult to do with previous technology.

4. CONCLUSIONS

Ubiquitous technology for a ship is not just replacing wired network with wireless network. It will capture various sensing data and evaluate them to upgrade previous systems installed on board. In addition, it is highly expected that ubiquitous technology will provide better services to crews and passengers. What one should bear in mind is that ubiquitous technology should be applied flexibly according to the type of ship being applied. For commercial ships, transporting cargo safely to destinations within a given period of time will be most important, while efficient and safe management of crews and passengers will be a key issue in passenger and military ships. Fire prevention will be a key common issue for most ships. If appropriate services are provided using ubiquitous technology satisfying the ship's purpose, convergence of ubiquitous technology and ship technology will be successfully realized.

However, there are yet a few challenges left. The most important one is that additional network is necessary since wireless network cannot guarantee that there will not be data loss during communication. In this research, PLC is used as a backbone network since it has the convenience of not having to install all the wiring. However, the reliability of PLC is depends much on the state of power systems, which differ from vessel to vessel. During our test on the test ship, PLC could not reach up to wheelhouse, so monitoring was only possible inside main engine room. These problems should be addressed on case by case basis.

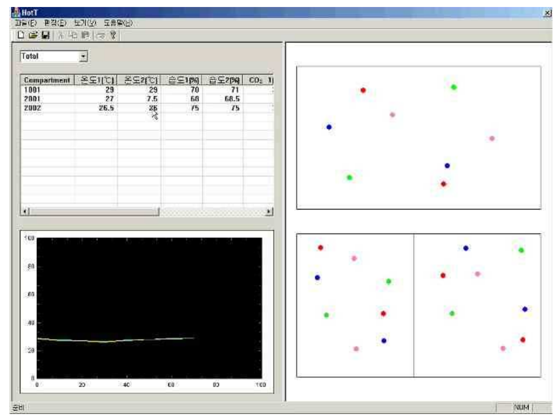

Figure 8. Prototype of fire prevention system

5. ACKNOWLEDGMENTS

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