A Study on the Performance Evaluation of Container Tracking Device based on M2M

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***Abstract*—A M2M-based container tracking device is a device installed inside container to detect the open/shut status of container door. In terms of the main features of the device developed in this study, it can not only detect the open/shut status of container door but also perform inquiries on the status of inside container environment and shocks received by container during its transportation upon installing temperature, humidity and shock sensors. This paper focused on the performance evaluation via trial operational test of container safe transportation surveillance & tracking, that monitors in real-time the security status of freight from departure to arrival.**

***Keywords*— Container, Tracking, M2M, Performance evaluation**

I. INTRODUCTION

According to the Container Tracking and Security Market 2012-2022 analysis, companies and organizations in many areas have a need to track and ensure security of their freight assets being transported around the world. In addition to increasing terrorists' threats, freight thefts and biological weapon terror threats, many containers become lost during transportation with increasing cost of goods that go bad. Accordingly, protection of containers through tracking and ensuring security is effectively being utilized in the commercial field, and an analysis forecasts that the container tracking and security market will see a strong growth in the next decade [1]. In particular, as the container tracking market is being rapidly growing since 2000, there is a possibility that it could see a significant scale of revenue. The world is engulfed in the wave of economic recession and there still are regions that are facing a crisis. However, the world's trade volumes are increasing exponentially. The container transportation industry might be experiencing difficulties but the number of containers (TEU) has been increasing in the last several years, which will continue on as it become a catalyst of the growth container tracking and security market. In 2012, the US announced an act that mandates all container freights coming into the US to be installed with security devices certified by the US Customs to verify that containers have not been opened during transportation. In addition to the US, the EU reinforced its logistics security by enacting 'marine & port facilities security regulations' that even mandated the recommendations in the ISPS Code provisions of the International Maritime Organization (IMO). It also legalized logistic security regulations that focus on fulfilling the corporate logistics security system (SAFE Framework) of the World Customs Organization (WCO) with continuous efforts to reinforce logistics security by developing and operating an import freight scanning system. Advanced nations including the US and the EU are developing electronic seal and container security devices and standardizing technologies to prevent any bottleneck in logistics flow while reinforcing security measures. They are moving quickly to preoccupy the market in addition of increasing R&D investment. Representative electronic security devices of freight container include electronic seal (eSeal) using active RFID (Radio Frequency Identification) technology and container security device (CSD) of IEEE 802. 15.4b. Active RFID with longer recognition distance compared to passive RFID tag that can be easily applied to metal object is being used for port & inland logistics transportation management system and container protection for metal containers. The eSeal that uses the technology in this paper is installed on the outside door handle of freight container. Upon detecting any abnormal opening of container door by an outsider or any attempt to open door abnormally, it notifies nearby reader while maintaining a log.

The CSD is installed inside freight container to detect any loss or theft of container, as well as any attempt to infiltrate container. While there isn't any international standard for container security device currently, the US Department of Homeland Security (DHS) has announced a technical specification required by the US Customs and Border Protection (CBP) [2]. Accordingly, various companies centering on GE (US) established Commerce Guard and Savi (US) and CIMC (China) are actively carrying out related R&D activities. However, in the midst of a situation where companies across the world are competing fiercely, there isn't any competitive product in Korea that could compete with foreign products as of now.

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Accordingly, this paper explains the Advanced Container Security Device (ACSD). ACSD satisfies the user requirement of real-time identification of container position by applying M2M (Machine-to-Machine) technology that uses mobile communication technology. And to evaluate the performance of ACSD and system, we introduces the trial test result which has been applied to container freight being transported between Korea and Poland, while also verifying the reliability of the paper [5].

The composition of this paper is as follows. Chapter Ⅱ examines the future direction of development and advancement of electronic security devices through related researches and comparatively analyzes the features of container security products. Chapter III explains the CSD system using the ACSD developed in this paper. Chapter IV evaluates the system performance through a trial services domestically as well as between Korea and Poland. Chapter V will conclude this paper.

II. RELATED RESEARCH

This chapter examines the future direction of advancement of container security devices and comparatively analyzes the features of a competitive companies' products and ACSD.

Since the early years of logistics using container, plastic or metal "seal" of conventional bolt barrier was used through one or more door hasp mechanisms for container security. Since 2000 in which the importance of container security was emphasize along with IT advancement, eSeal was developed applying active RFID technology, which detects any abnormal opening/shutting of container door upon installing. However, eSeal has the weaknesses of easily breaking down as it is attached outside container door and not being able to be reused. Improving the weakness of eSeal, the development of CSD became active according to the CSD requirement document presented in 2007 by the US DHS for detecting any illegal opening/shutting of container door. As it is installed inside container, CSD can be reused. Since then, ACSD (Advanced Container Security Device) is currently being developed with improved performance, which not only detects any illegal opening/shutting of container door but also monitors inside the container and detects illegal immigrants. In terms of future direction, it is expected that intelligent container will be developed with devices that perform ACSD function are preinstalled inside container rather than separately attaching eSeal device to container. Table 1 compares and analyzes the features of M2M-based container tracking and security devices in commercialization.

TABLE 1
FEATURE COMPARISON

	Starcom	Kirsen
	TRITON	CMD500-S
Shape		
De/attachment	•Left wall	•Center
Weight	•150g	•1500g
Size	•195×96×40(㎜)	•200×150×100(㎜)
Communication	•Zigbee •CDMA, GSM option	•GSM •GPS, RFID option
Battery	•5000mAh Li-lon	•3 years (2 per day)
Position	•GPS	•GPS + Cellular
Status	•Door, illumination	•Illegal infiltration, temperature, humidity, shock, vibration, slope
Temperature	•-40℃-60℃	•-30℃-85℃

The two devices can be used in container security related areas such as the UD DHS CSI, SAFE Port Act, C-TPAT, 10+2 system, etc. Using a clamp type (C-Clamp) auxiliary device, Kirsen's CMD500-S is attached outside container door at the center and detects opening/shutting status of door using breach [3]. It also provides a log of changes in container status during transportation by installing temperature/humidity and shock detection sensors. Using magnet between container wall and door, Starcom Systems' TRITON is attached to detect opening/shutting status of container door by using proximity sensor [4]. It also provides a log of container status during transportation by attaching temperature/humidity sensor. However, CSD that does not include shock sensor cannot detect any shock received by container.

III. INTRODUCTION TO ACSD

The shape and framework of ACSD prototype and the definition of payload for data communication are as follow.

A. About the Prototype

Fig. 2 shows the parts of container security device. This device has been developed according to the requirements of the US DHS, marine shipping companies and shipper. The device is attached on crack between outside wall of container door and the door at an appropriate height at which freight will not be damaged. Using magnetic sensor, it detects container door opening/shutting status and provides a log of the status of container during transportation through temperature/humidity and shock sensors installed. As it is installed inside container, there is a low risk of damage for ACSD that can also be reused. It has been developed to allow communication at any parts of the world with communication stations as the device is M2M-based.

Fig. 1. The shape of ACSD

B. Framework

As shown in Fig. 2, the M2M-based container tracking system framework consists of container tracking device, interface and container tracking control information system. The container tracking device should collect information (position, temperature, humidity, shock, door status) required by global supply chain constituents and be usable even in poor logistics environment. The real-time communication interface needs to consist of interface with mobile carrier's communication station and protocol required for data collected from container tracking device to be sent to container tracking control information system. The container tracking control information system is software for displaying in real-time visual information to constituents of global supply chain once the data collected from container tracking device has been sent via real-time communication interface. The middleware of container tracking control information system consists of middleware that sends only required data to monitoring system by collecting and filtering data from container tracking device, and web-based monitoring system that displays in real-time via electronic map to users the data refined by middleware, and mobile-based system that can send information even via smart phone.

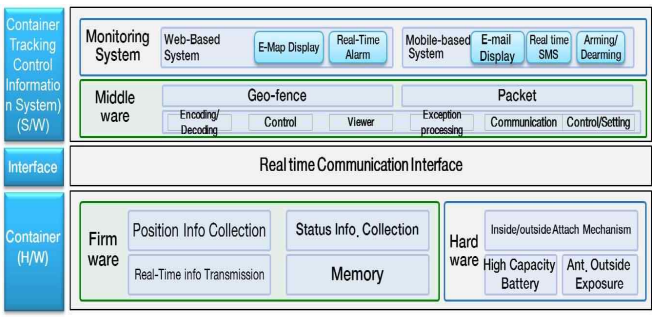

Fig.2. CSD Framework

C. Definition for Payload Data

As shown in Table 1, data being transmitted to/from container tracking device included device ID, status info such as position, temperature, humidity and shock, as well as battery and transmission cycle information. Such information was defined according to the features that can be provided by hardware and protocol rules.

Table 2. DATA DEFINITION

Classification	Content	Length
Index	Index of log stored in the device	2byte
Protocol ID	ID of corresponding protocol	1byte
Device ID	Unique number for distinguishing devices	8byte
Date & Time	Display of event occurrence and info transmission time	6byte
Position Data	Display of current position	11byte
Temp	Value of temperature measured in sensor module	2byte
Humid	Value of humidity measured in sensor module	2byte
Shock	Vector sum of the X, Y, Z axis of acceleration sensor	2byte
Door Status	Opened or closed	1byte
Remaining Battery Power	Display in % remaining battery power	1byte
Device On/Off	Display Device On, In-Process, Off status	1byte
Transmission Cycle	Cycle of transmitting information to server	1byte
RSSI	Display of signal reception sensitivity	1byte
Error Status	Storage of Error Code of error and malfunction of transmitted information	1byte

IV. DEMONSTRATION TEST

This chapter introduces a result of overseas trial test for demonstration and reliability check between Korea and Poland which was conducted to verify the performance of ACSD system developed in this research.

A. Demonstration Test

The ACSD system was applied to a container filled with freight being transported from Paju to Busan Port to Poland, as shown in Fig. 3, with the assistance from Company L to conduct an international trial service between Korea and Poland. The objective of the trial service was to verify the features during container marine transportation and it checked the status of complete transmission of data collected from the device to server to operating server DCP when the container installed with the device passes through the following base points.

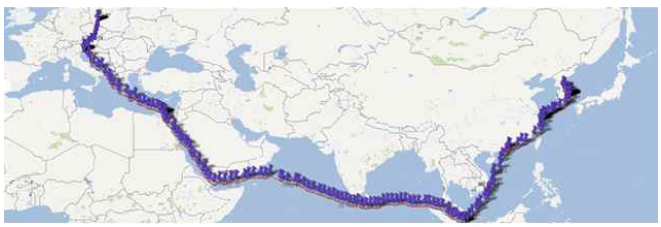

Fig.3. Test Section

TABLE 3. DATA TRANSMISSION AND RECEPTION ANALYSIS

Order	Section	Trans. Cycle (min)	Set Interval (min)	Trans. Frequency (Server Reception)			Trans. Omission Frequency
				Cycle Trans.	Interrupt	Total Reception	
1	Domestic	10	20	2	-	2	0
2	Domestic Inland → Incheon Port	60	360	6	10	16	0
3	Incheon Port → Belarus	180	34,560	191	22	213	1
4	Belarus → Destination (Poland)	60	1,320	22	-	22	0
Subtotal			36,260	221	34	255	-

B. Performance Evaluation

The main firmware features of the container tracking device, which are information collection, real-time information transmission/reception and memory storage features, are features that can be performed on the premise that the main hardware features explained earlier operate normally. This indicates that when the information collection, real-time information transmission/reception and memory storage features used during the trial operation operated normally, the main hardware features of the container tracking device also operated normally. In regards to the main firmware features of the container tracking device, which are information collection, real-time information transmission/reception and memory storage features, number of data transmitted according to information transmission cycle and number of data received will be analyzed for verification. Since the real-time information transmission/reception feature can operate with the prerequisite of information collection and memory storage features, normal operation of information collection and memory storage features can be also verified by analyzing the number of transmitted data and the number of received data.

It is expected that the total number of data transmitted according to the information transmission cycle set as shown in Table 3 would be 222 but the actual number of information received by server was 255 based on trial operation results. This is a sum of 221 times of transmission according to set cycle and 34 times of interrupted transmission that occurred by detecting through shock sensor and door opening/shutting. Except for the number of interruption from the exceptions that occur during transportation, the final number of reception was 221 that is short by one session from the initially expected number of transmission of 222. This is a result one session of information transmission that was omitted in the section transporting from Incheon Port to Belarus and it is estimated that one session of information transmission was omitted due to reasons of real-time information communication network infrastructure (communication station).

It was confirmed through such analysis of data transmission and reception frequencies according to information transmission cycle that the main firmware features of container tracking device used for the trial operation operated normally.

V. CONCLUSION

The M2M-based container tracking system framework presented and the system developed in this paper were evaluated for its performance through trial operation. The CSD system that has been verified through performance evaluation enables shipper and forwarders that need real-time tracking of container the most among the constituents of global supply chain to effectively establish their global supply chain plan. It is difficult to collect in real-time information required by users through conventional container tracking system. However, in the case of container tracking system presented in this paper, effective supply chain management can be expected such as inventory control and production management by collecting and utilizing in real-time container information (position, temperature, humidity, shock, door opening/shutting) required by users upon utilizing M2M real-time communication technology.

In addition, logistics companies such as forwarder, transportation and shipping companies directly verified freight arrival/delivery by utilizing their or partner's manpower at each logistics base point. Among the container tracking control information systems presented in this paper, the main middleware feature of Geo-fencing enables real-time verification of freight arrival/delivery in office. This feature allows logistics companies to save time and cost involved in verifying freight arrival/delivery status with the expected effectiveness of improving their credibility by notifying shippers that their freight is being transported safely.

Upon the logistics paradigm shift mentioned earlier and background of study, logistics security is being reinforced across the world through regulations and policies. The container tracking system according to the M2M-based container tracking system framework presented in this paper can satisfy safety/security regulations required in the US, Europe and Asia. Accordingly, it has the expected effectiveness of simplification of customs procedure and provision of swift clearance benefits at the level of global supply chain management.

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