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RFID-Based RTLS for Improvement of Loading Productivity in Container Terminals

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Abstract : *Shipping companies consider most of the ship turnaround time as a critical factor when selecting a calling port for reducing costs. So, many researchers have been studying for the optimization of pre-planning and high-performance of the Gantry Cranes (GCs) in container terminals for faster loading and unloading. Therefore, in this paper, we propose an RFID (Radio Frequency Identification)-based RTLS (Real-Time Location System) for reducing the ship turnaround time in ubiquitous port environment. In addition, pre-planning based on ubiquitous computing environment will support the GC and Yard Tractors (YTs), and reduce ship turnaround time more effectively. Especially, the proposed method enormously enhances the productivity of loading for the twin-lift system. It will reduce the whole lead-time in the process of port logistics.*

Key words : *RFID, RTLS, Ubiquitous computing, Turnaround time, Twin-lift system, Productivity*

1. Introduction

In recent years, the worldwide container handling volume is rapidly and continuously increasing, so the shipping companies try to reduce their shipping costs by using mega vessels to the ports. About 8,000TEUs (Twenty-Feet Equivalent Unit) of mega container vessels are operated in these days and 12,000TEUs of super-mega vessels will be operated in the near future [1].

Shipping companies consider most of the ship turnaround time as a critical factor when selecting a calling port for reducing costs. So, many researchers have been studying for the optimization of pre-planning and high-performance of the Gantry Cranes (GCs) in container terminals for faster loading and unloading [2]. For the loading productivity, the operators of terminals start to adopt high performance of the twin-lift GC in these days. Therefore, in this paper, we propose an RFID (Radio Frequency IDentification)-based RTLS (Real- Time Location System) for reducing the ship turnaround time in ubiquitous port environment. This paper proposes RFID-based RTLS for enhancing the performance of container terminal operation. For more efficient loading of containers, we propose a new data format applicable to the undefined 'N Byte' parameter field described in ISO/IEC 18000-7 format [3], which is in a standard document of RFID 433 Mhz for containers. Such an RFID message format is encapsulated to RTLS physical layer Service Data Unit (PHY SDU) [4].

If we use this RFID-based RTLS, the crane drivers and inspectors are able to get the real-time container position from RTLS as well as proposed RFID formats such as a container POD (Port of Destination), size, weight, transit, etc. while working in the yard and quayside. In addition, pre-planning based on ubiquitous computing environment will support the GCs and YTs, and reduce ship turnaround time more effectively. Especially, the suggested method enormously enhances the productivity of loading for the twin-lift system. It will reduce the whole lead-time in the process of port logistics.

2. Previous Works

Some of the advanced ports installed with latest IT technologies have better competitiveness to the lagged ports. There are some researches adopting RFID and the wireless network technologies for their faster speed, more secured, and support automated work procedure in the logistics infrastructure. Then the uniqueness in 433 Mhz RFID is that it can trace container's data from the long distance about 100m in real-time. But it also has a microscopic awareness function sensing humidity or damage in the containers. This technology is nowadays adopted and utilized in U.S and England armies for reinforcing fast and secured procurement of military supplies.

2.1 Limitation of using RFID in Container Terminals

A Current RFID technology has been known that it is

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limited to read precise position in busy areas like container yard and container berth, in which a number of RFID tags are congested. For this reason, loading and discharging works at container yard and quay side have been excluded in the scope of project of 'RFID Efficiency and Performance in Port Logistics' organized by Korean Maritime Affairs and Fisheries Office, and even same cases in SST, APEC STAR-BEST Project, APL Projects [5].

As matter of fact, currently developed 433 Mhz RFID has such a limitation to read and trace the exact position of each container tag in the circumstance of a number of tags are congested in the limited area like container yard and berth. It says that RFID reader can read the existence of tag within certain distance, however, unable to catch up each container's precise position information in real-time. From that ground, it has activated a need of more advanced technology development recently RFID-based RTLS is on research and development to complement such a limitation of RFID above mentioned.

2.2 RTLS (Real-Time Location System)

The RTLS is to provide regular position information of tagged assets within a facility. A facility could be outdoors, as with truck depots, or indoors, as with container terminals. RTLS tags are battery operated radio transmitters that are attached to assets, items, people, etc. The RTLS tags transmit messages to the readers and provide a unique ID for the asset as well as certain status information about the tag and asset. The wireless communications protocol used to communicate data between the tags and the readers.

The air interface would define such things as the antenna characteristics of the tag and reader, the transmit frequencies, transmit power, modulation, coding, bit rate, multiple access scheme, interference tolerance, and message structure. RTLS Readers receives signals from the tags and demodulates the signal to obtain a tag message.

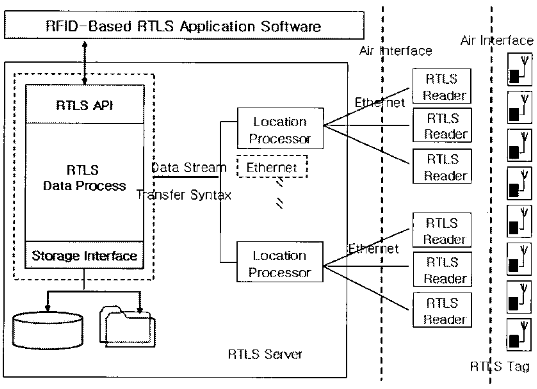


Fig. 1 RTLS Configuration

An important function of the reader is to determine the time-of-arrival of the message relative to some time base in the system. The output of the reader is tag messages and the corresponding time-of-arrival information for the message. The RTLS network provides a communication medium between the reader and the RTLS server. This network must be able to handle the message traffic from all tags and readers in the RTLS infrastructure. The RTLS server aggregates data from the readers and determines RTLS tag location. The RTLS application software receive RTLS tag location and status information through the RTLS server.

3. Container Terminal Using RTLS

3.1 Tag Protocol Specification of RTLS Based on 433 Mhz RFID

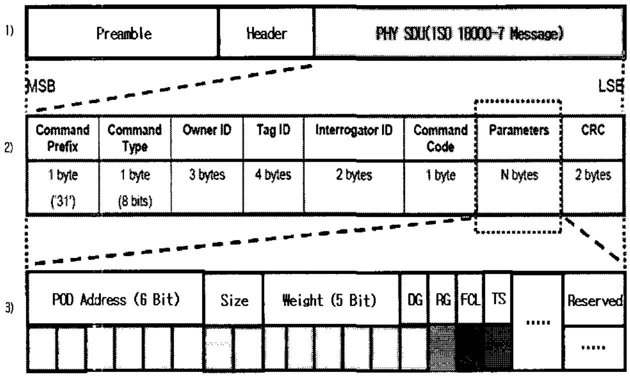
The RFID standardization is to prescribe wireless interface or protocol so that its tag and reader are able to translate and communicate data and information. It is in process as ISO 18000 series by ISO and JTC1-SC31 WG4 SG3 joint technology research of IEC. Table 1 shows the standard provision of ISO/IEC 18000 series [6].

Table 1 ISO/IEC 18000 series standards

- 18000-1 Part 1 – Generic Parameters for the Air Interface
- 18000-2 Part 2 – Parameters for Air Interface Communications below 135 Khz
- 18000-3 Part 3 – Parameters for Air Interface Communications at 13.56 Mhz
- 18000-4 Part 4 – Parameters for Air Interface Communications at 2.45 Ghz
- 18000-5 Part 5 – Parameters for Air Interface Communications at 5.8 Ghz
- 18000-6 Part 6 – Parameters for Air Interface Communications at 860 to 960 Mhz
- 18000-7 Part 7 – Parameters for Air Interface Communications at 433 Mhz

The RTLS physical layer accepts service data units (SDU) from higher layer. The RTLS physical layer specification provides location awareness and operates in the 433 Mhz band. There are mechanisms in this physical layer specification that facilitate the development of semiconductor devices and infrastructure, which is backwards compatible with ISO 18000-7 RFID tags. Fig. 2

shows location aware 433 Mhz air interface for ISO 24730-3's physical protocol data unit format [7].



1) Source : Location-Aware 433MHz Air Interface For ISO 24730-3
2) Source : ISO/IEC 18000-7 Standard Message Format
3) Proposed Field Item And Specification

Fig. 2 RFID message format is encapsulated to RTLS PHY SDU

Table 2 shows our suggested field item and specification for the N Byte's Parameters.

Table 2 Suggested message field item and specification

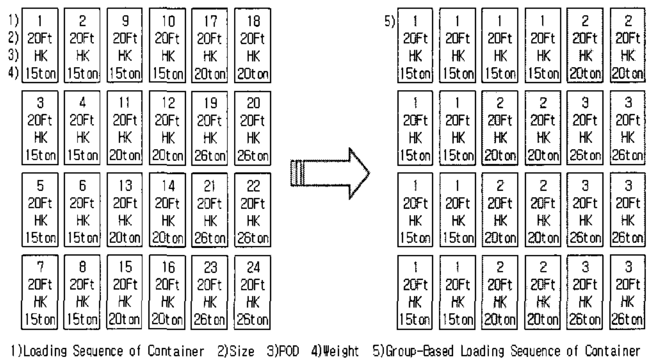
Suggested field item	Bit	Specification
POD	6	Supports 64 of main ports
Size	2	Supports 20, 40, 45 feet
Weight	5	Supports 32 classes of weight
DG Cargo	1	Dangerous Cargo - number one given
Reefer Cargo	1	Reefer Cargo - number one given
FCL	1	Full Container Load - number one given
TS Cargo	1	Transit Container - number one given

3.2 Terminal Operation System using Suggested RTLS

The shipping companies send cargo information for loading and unloading to terminal through EDI and the terminal makes pre-planning based on the received information. The container terminal makes plan for loading and unloading, and it notifies the planned loading sequence and a stowage plan to the shipping company. While loading containers in the terminal, the inspectors of shipping company check the loading sequences of containers as planned in container terminal. At this point, the inspector confirms to precede the loading unless there is any damage or out of the sequence. Especially, a pre-planned planning is different from the real time situation since the situation happens in the terminal changes often [8].

When shipping company makes the loading instruction plans, the heavy-weight-containers are loaded prior to the light ones and stacked on the bottom tier. It is the most vital element among other factors for the stability. For this reason, the Transfer Crane (TC) driver must keep the work sequence in order, after re-stacking and re-marshalling. In case that TC driver doesn't follow the plan and load a container to Yard Tractor (YT), then the YT can't load container to the ship and has to wait his turn. Such unexpected changing of the work sequence generates unnecessary re-handling of containers, the waiting of YTs, and delaying of ship turnaround time.

There is an exception to allow the changing of loading sequence by a terminal operator, when those containers have the same POD, size, and weight



(a) Non-group-based loading sequence (b) Group-based loading sequence

Fig. 3 Suggested pre-planned yard allocation

The Fig. 3(b) shows pre-planned yard allocation applying RFID field suggested in Fig. 2 of RTLS. The suggested yard allocation is based on current yard allocation algorithm. What is difference from the existing algorithm is that it would not apply container-loading sequence to each of independent container, but shall apply to each of group in the same of Port of Destination (POD), container size, container weight, etc. Container Terminal follows pre-planning and transmits the loading sequence by group in POD, container size, weight, and etc. to the TC.

Fig. 4 shows the loading operation system of the container terminal in the ubiquitous environment. The TC driver can get such necessary information of POD, container size, weight, etc in real time through RFID-based RTLS tag and its working data after yard container re-stacking or re-handling is refreshed in real time even without touch-screen confirmation and automatically transmitted to terminal operation system.

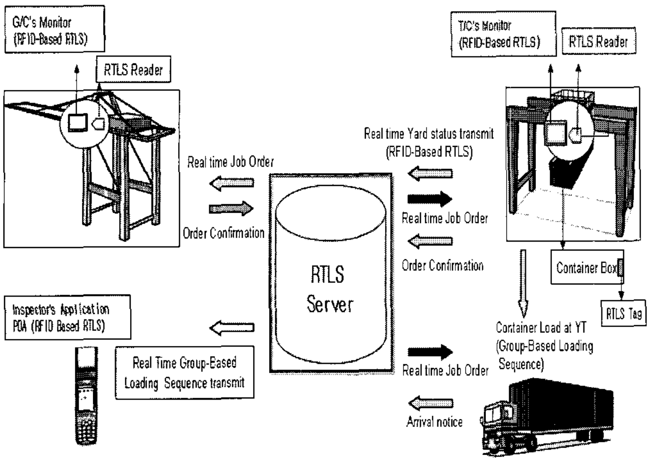


Fig. 4 Suggested loading operation system for ubiquitous computing

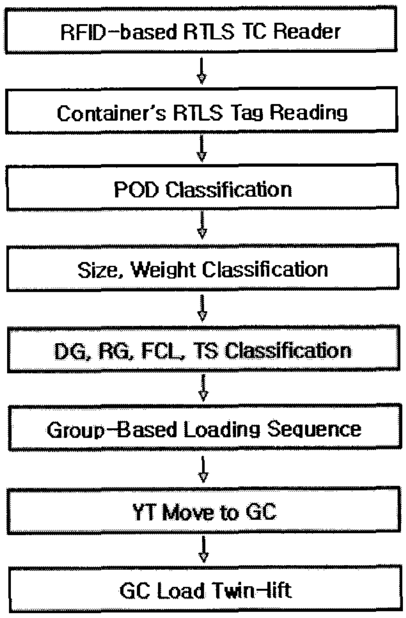


Fig. 5 Loading operation of twin-lift using group-based loading sequence

Terminal operating system transfers the loading order of each group with RTLS embedded system like inspector's PDA in real time. Yard's TC driver can minimize its working movement when stacking the container based on pre-planning to the YT. The TC driver can minimize its working movement when stacking the container based on pre-planning to YT. The YT after being stacked a container can move to the GC. The inspector inspects the loading order of the container that is arrived at GC referring to the loading order of it the terminal operation system in real time. Then he checks the damage condition and e-seal of the container and load it to the ship before container loading, the container loading sequence by each group is automatically shown in the inspector's RFID-based RTLS checker, as RTLS reader is equipped in the spreader of GC.

By the way, the twin-lift GC enhances the loading productivity and reduces the number of YT's driving cycles than using single hoist GC. However, the two containers lifted by a twin-lift GC should have similar characteristics such as POD, weight, etc.

The group number is decided by the loading operation of twin-lift using RFID-based RTLS as shown in Fig. 5.

For example, the twin-lift should consider the width of the two containers. Each container lifted by the twin-lift should not exceed 40 feet and the two containers should be balanced maximum of 10 tons for each. Therefore, the re-handling for the twin-lift requires much workload before loading in GC.

The suggested RFID-based RTLS supports twin-lift operation more efficiently. The RFID tags read and inform real time messages to the monitor in the TC. Since the suggested system operates with a group based loading sequence, the workload of re-handling in TC is reduced.

4. Performance Evaluation

In order to evaluate how the suggested RFID-based RTLS can help the improvement of working efficiency and performance, the simulation has been conducted. Rockwell Software ARENA version 9.0 has been used for a modeling program.

4.1 The constraints and parameters for simulation

The simulation does not consider other factors listed below and constraints for the container terminal.

Constraint conditions

1. Initial pre-planned yard allocation is based on current algorithm and container loading is to be sequenced according to each group by POD, container size, weight, etc.
2. The necessary number of group and its container number in each group for simulation are to be referred by provided EDI information from shipping company.
3. The possible scenario of twin-lift GC is to be estimated from EDI information.

4. The mean time of turnaround time of YT will be applied.
5. Cycle time of YT is to be considered for simulation of twin-lift GC.
6. It applies 1.5 conversion ratio (=TEU/no. of VAN) in container proportion. (The range of the ratio is 1 to 2. (Closer to 1 means there are more 20feet containers than 40feet, and 2 is vice versa)
7. The input data for a simulation considers only the volume of berth. An amount of volume that is transported from the gate in/out does not consider.
8. The model of container terminal design follows M/M/S queuing

The parameters are summarized in Table 3 and the facilities and equipment requirements.

Table 3 Parameters for simulation

Classification		Establishment	Remark
Quay side Length		1,050m	One berth
Number of GC		1	Single hoist GC,
			Twin-lift GC
Performance of GC		Real Capacity ⇨ 28Van/h	Theoretical Capacity ⇨ 42Van/h
YT	Operation system	GC⇔YT⇔TC	Group-Based operation system
			Existing operation system
	Cycle time	6.2min/cycle	Average cycle time
TC	Throughput	15.4Van/h	Average throughput

4.2 Results

Fig. 6 shows a loading productivity of LPC (Lift per Call), which is a total number of containers of loading for a ship. The loading productivity of a single hoist GC is estimated 28 per hour with consideration on the several interference factors of the container port [9].

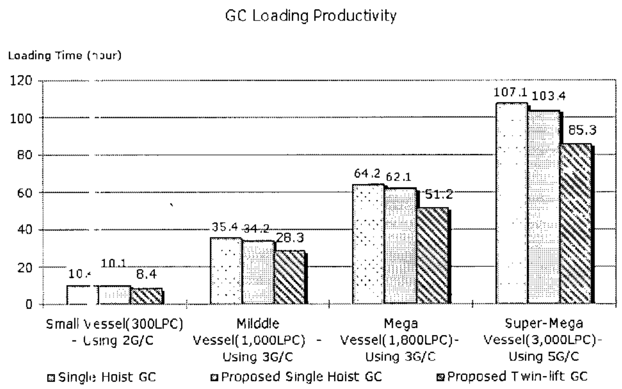


Fig. 6 Productivity of loading by each vessel

The proposed method shows the loading productivity when RFID based RTLS is applied. The single hoist GC applied the proposed algorithm reduced about 30 minutes, and 4 hours for loading of small vessel and super-mega vessel respectively. Especially, the twin-lift GC applied proposed algorithm reduced about 2 hours and 22 hours for loading of a small vessel and super mega vessel respectively. These results are examined with a single GC environment.

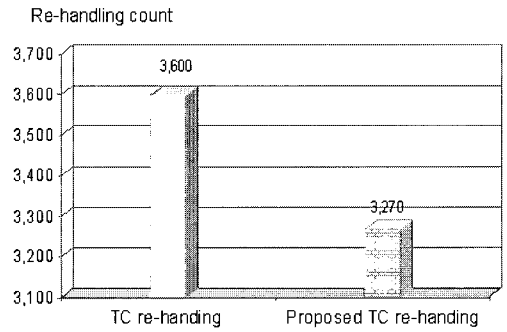


Fig. 7 TC re-handling count about loading work

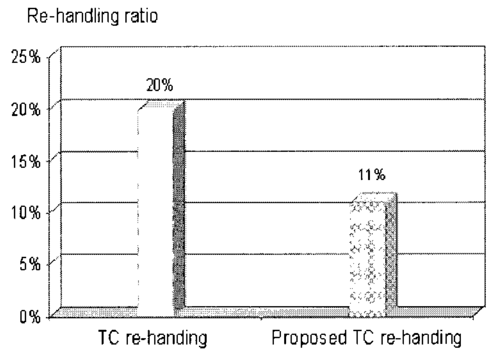


Fig. 8 TC re-handling ratio about loading work

Fig. 7 and Fig. 8 shown a TC re-handling about loading work. When 1,500Vans is loaded with G/C, the operation of 1,800 times is occurred and needed 20% re-handling at the current yard as shown in Fig. 8. When the proposed algorithm is applied to T/C, another 7% of re-handling occurs. So it is improved 13% of re-handling.

5. Conclusion

This paper proposes an RFID-based RTLS for container terminal and its efficiency of which to enhance the performance of container terminal operation system. It showed better performance when there is more volume than less volume. So we expect that a container terminal adopt our suggested system would have the superior reputation in this business. This research should be further developed and studied on the parameters of the container terminals to reinforce RFID tag field for the efficiency.

The other parameters proposed in this paper should be considered for the next research. Secondly, the middleware supporting the suggested tag format in this paper also need to be studied. Thirdly, the modeling of the twin-lift system should be experimented with detail descriptions and parameters for the various situations in the ubiquitous port environment. Finally, the information applied for the advent of the next super mega container of a new and remodeling port is requested such as estimation of required number of GC, YT, and TC.

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