STAPID: A Secured Approach for Container Monitoring and Tracking

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***Abstract*—STAPID is a secured asset tracking pilot device for monitoring and tracking of transported assets. This paper presents a container security and monitoring device based on WCDMA (wideband code division multiple access) communication between an e-seal mounted on the container and a management server that oversees the freight movement process. This proposal consists of: real time communication capability on the asset location during transportation; secure mechanism to prevent unauthorized removal; secure hardware structure against tampering; and status-of-the-art visualization techniques for real time monitoring with graphical information. STAPID device is designed to send frequent messages to the end-users about their containers status and any shock beyond a set level that may alert customers about any breach or possible theft to their valuable goods.**

***Index Terms*—transportation logistic, RFID identification, container security, WCDMA communication**

I. INTRODUCTION

With increasing global competition, enterprises are facing on-going challenges in managing their expensive and critical Assets. Visibility information such as presence and location has significant value to enterprises. Such information represents the characteristics and the trends of the business operations. Enterprises who have visibility into their supply chains can best adapt to the dynamic business environment and have a better chance to be successful in a world of globalization competition [1]. Especially real time monitoring capability is an enabler that allows enterprises to have a clear visibility into presence and location of their critical assets that are important to their day-to-day operations.

Since the foundation of Auto-ID center at MIT, Passive RFID, has been considered as the primary choice for asset visibility and asset tracking [2]. However, due to some limitations, the mass adoption of technology has yet to come. Firstly, the limitations in environments with metallic or liquids surroundings have minimized its uptake [3]. This occurs because the radio waves are absorbed by liquids and are attenuated by steel structures, which results in less than 100% read rate reliability. Secondly, the limitation of reading distance is another reason. Most passive technologies (e.g. UHF, HF) generally provide less than 10 meters of reading distance in maximum. However, many organizations (e.g. military, large wholesalers, large retailers, customers, etc) want to have a visibility on their moving assets which are generally delivered by containers. Such environment will requires installation of too many readers and it will be too costly solution [4].

After September 11 attacks, there have been growing needs for real time asset tracking to provide visibility along the delivery chains and to protect assets by reducing tampering and unauthorized removal (especially real time asset delivered by container) [5]. To accommodate such needs, ISO published its standard on Electronic Seal (E-Seal) in 2006 (ISO 18185 series). However, due to the limited capabilities (i.e. it needs fixed reader location with reading distance of 100 meters; it cannot detect the location of container in real time if a reader is not installed within the reading distance; it cannot provide protection mechanism for tempering) and high cost of solution, the industries have not adopted E-Seal so far.

The aim of this proposal is to develop a WCDMA based container security device which consists of: real time communication capability on the asset location during transportation; secure mechanism to prevent unauthorized removal; secure hardware structure against tampering; and different types of environmental and shock sensors to monitor the status of the container. In addition to that a status-of-the-art visualization technique for real time monitoring with graphical information system has been developed.

Manuscript received January 7, 2016; revised May 1 2016.

doi: 10.18178/jtle.4.2.167-172

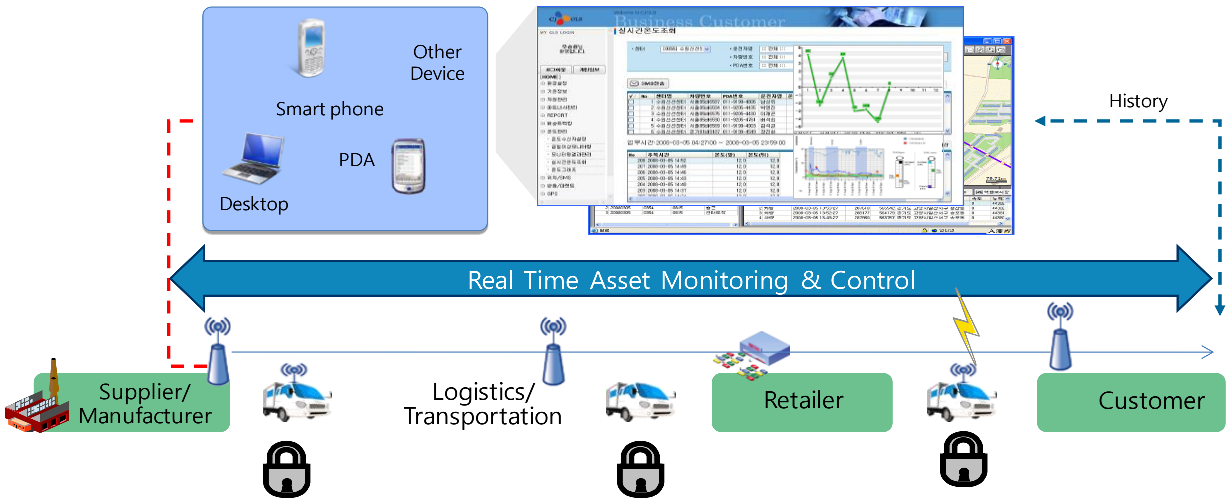

Figure 1. Concept of real time monitoring and tracking of assets

Fig. 1 shows the concept of real time asset monitoring and control in which organization can have clear visibility of their transported assets and can ensure on-time delivery of their valuable goods.

The remaining of this paper is organized as follows; section 2 provides detailed literature review on related works on container tracking and monitoring. Section 3 presents our real time container tracking and monitoring system. Section 4 presents a study case for sample container tracking and finally Section 5 concludes this paper by stating the main findings of this work.

II. Literature Review

Jedermann *et al*. [6] combined wireless sensor network and Radio Frequency Identification (RFID) for robust container tracking. They used a high performance embedded processor to process the local data of each node and thus reduced the communication volume. However, to realize such a system in real-life scenarios it would require deploying a large number of sensor nodes which increases the system cost. Asosheh *et al.* [7] proposed a cargo tracking system using Satellite, RFID and Global System for Mobile (GSM) communication. This conceptual design used the above technologies to communicate the last status of the container to the customers using Short Messaging Service (SMS). However the authors have not realized their proposal in real container tracking. Kim *et al.* [8] worked on developing smart containers using RFID and wireless sensor network to enhance container security by creating an ad-hoc network. They proposed a dynamic mesh container network among neighboring containers. This mesh is self-configuring and it can change dynamically for each new physical realignment of containers. They also proposed the concept of Mobile Edge Computing Devices (MECD) to process large scale data and sensor network in a highly scalable and efficient approach. MECDs collect raw data from sensor network and perform necessary preprocessing on these data. Then MECDs communicate the processed sensor data with cooperative high-end computers. In their implementation CrossBow devices has been used and MECD to connect sensor network to servers via Wi-Fi, Zigbee and Cellular communications.

Vasseur and Dunkels [9] presented a container tracking and breach notification method using a sensor mounted in container (CommerceGuard from General Electric). This is a semi-IP based system as the end points are not IP but they communicate with IP based readers along the supply chain. The readers communicate with devices on containers using low-power radio and proprietary protocol and they are connected to internet to communicate with database. IBM has also proposed a container tracking system known as Secure Trade Lange (STL). TSL uses a security device (tamper-resistant embedded controller TREC) which communicates with database to track container movement. This TREC does not requires reader points unlike the CommerceGuard system as it can directly communicate with internet using on board General Pack Radio System (GPRS). Rizzo et al. [10] defined a seal as a device that must be broken before access to that object can be obtained. They developed an electronic seal composed of plastic body linked to an external cable by two connections. The unauthorized opening is detected if these connections are broken. Active RIFD circuit with low frequency transponder reader is placed on the sealing body. Also a passive RFID chip is installed on the connection cable to ensure proper closure of container. The experimental analysis proved that full power communication between the seal and reader becomes efficient at mean distance of 21.9m and the communication region has a cone shape. Shin et al. [11] proposed a new communication standard for real time tracking of containers to realize a global supply chain management. These authors have used Wideband Code Division Multiple Access (WCDMA) and GSM to communicate the container location and various sensor parameters with collecting servers to allow visibility of container data to customers.

Ting *et al.* [12] conducted a feasibility evaluation of RFID based methods for container tracking. They conducted series of experiments on a container terminal and assessed factors affecting the use of RFID for container tracking. They concluded that RFID communication works well for container tracking in terminal areas whereas it cannot guarantee 100% accuracy indoors unless for small readability distance less than 10m. Lee *et al*. [13] developed a device to detect the open/shunt status of a container door and it can also sense the environment status inside the container and shock levels during its transportation. Their lock is installed inside the container at the crack between outside door and container body and it can detect open/shunt status using magnetic sensor installed in it. Their device allows communication at any part of the world with existing communication infrastructure.

Gnimpieba *et al*. [14] proposed the use of internet of things (IoT) and cloud computing technologies for real time tracking of goods. Their proposed system used RFID to identify the status of container and communication it using GPRS with data even storage. The storage is based on cloud computing and it allows easy scalability of the system as it is accessible anywhere and in anyhow.

TABLE I. COMMON APPROACHES FOR CONTAINER TRACKING COMMUNICATION

Emerging choice	Data range	Frequency	Advantages	Disadvantages
GPS	~100 m	300 – 915 MHz	Available in the vehicle tracking for outdoor environment	Not suitable for the indoor environment
Wi-Fi	~100 m	2.45 GHz	Using the existing Wi-Fi infrastructure to implement real time tracking	Power consumption due to increased data overhead of using the 802.11 x protocol
Bluetooth	~100 m	300 – 915 MHz	Low cost and available in most computers and mobile devices	Slower data transmission rate that Wi-Fi and very high power consumption
Ultra wideband (UWB)	~50 m	1 – 10 GHz	It provides very accurate localization of targets (tag)	It requires expensive infrastructure
Zigbee	~60 m	300 – 915 MHz	Low power consumption	Not widely available and it requires software technology for both technologies
GSM	> 300 m	900 MHz and 1800 MHz	Available in all mobile phones and it covers a very wide ranges	Required subscription to a cellular network paly and monthly payment
WCDMA	> 300 m	Mostly 2100 MHz	Available in all mobile phones and it covers a very wide ranges	Required subscription to a cellular network plan

III. PROPOSED METHODOLOGY

As presented in the previous section, there are various approached for container tracking and monitoring. This includes, GPS, Zigbee, UWB, Wi-Fi, GSM and WCDMA. Table I above presented comparison of various communication methodologies for container tracking and monitoring. As it is clear that WCDMA is more preferable because it has high coverage and also very good data rate compared to GSM.

Tracking of expensive or hazardous shipments add an additional security level in order to ensure the security of the tracked vehicles and containers from the start of the dispatch to the destination. This subsection explains the real-time tracking system scenario and analyses the security threats to this field.

A. *STAPID Device*

We designed circuit of SATPID after defining hardware components which is configured on SATPID. And we also designed case and mock-up. Fig. 2 shows hardware design and the role of each component is as follows:

CDMA is a telecommunication module which transfers real time information to server.

- It transfers location information that is captured by GPS in real time.
- It detects illegal open of freight with locking module and transfers in real time.
- It authorizes security key with USB module using encrypted communication with server.

GPS is a module which renders latitude, longitude. It calculates location information using triangulation method. GPS requires the availability of maps to provide so that the longitude and latitude are translated into a location in the map.

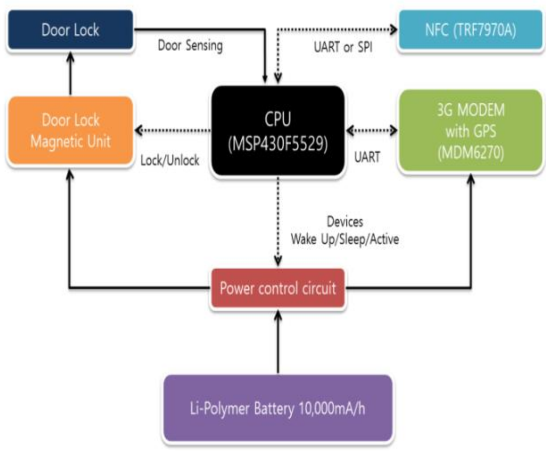

Figure 2. Schematic diagrams showing the components of STAPID device

Fig. 2 shows schematic diagram of the component of the STAPID device. The magnetic unit is locked by default and it can only be unlocked with the correct RFID tag even if the electronic circuit is destroyed or full damaged.

RFID authentication is used to lock and unlock the container using a predefined RFID tag, the role of the RFID module is as follows:

- Recognition of pre-certified security RIFD tag.
- Recognized secure information is providing to the CDMA module to perform a security authentication procedure.

- Lock is a container physical lock. It has both a mechanical and electronic features. It has the following features.
- Since lock arm is included damage sensor, it can detect illegal open.

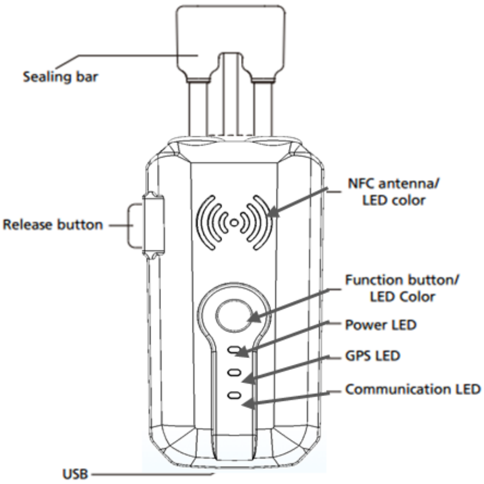

Figure 3. Diagram for STAPID device components

Fig. 3 shows the components of the STAPID devise (eseal); the sealing bar is padlock type with three legs. The release button is used to release the lock after the RFID card authentication. The LED indicates green for correct authentication and blue otherwise. The function button is used to activate the device for unlocking and there are three LED indicators for power, GPS and communication. The USB is used to recharge the batter and also as secondary authentication using special USB key. Fig. 4 shows photos of STAPD device for three different views. The circular white button at the centre is the function button while the square button at the side is for lock releasing.

Battery is a main power of eSeal to make it work. The lifecycle of battery is heavily dependent on the usage frequency (e.g. how many times the system transfer data). The battery has the following features:

- It cannot be removed from outside to prevent illegal open using power off.
- It can be replaced with a large capacity battery for long trip.

Figure 4. Photos for STAPID device showing the outside casing

B. Monitoring and Tracking Software

The monitoring software provides real time tracking of the STPID status, this software application which is known as business even center (BEC) is a web application that retrieve the device information and can interface with external map server (Google maps). As in the Fig. 5, the architecture consists of three layers: Device layer, Edge layer, Server layer. Through Device layer, information for different object can be collected and passed to middleware software that has three capabilities such as device driver management, device control, data filter & logger.

Event comes from device be managed by BEC for track and monitoring. BEC is software that manages event data, for track & trace and can manage operation log captured by other application or device. BEC can be integrated with legacy system or commercial WMS (warehouse management system) with minor efforts. Mapviewer is developed for tracking & tracing and can display the location of assets on the map and also able to show the status (stolen or broken). Authorization is performed by BEC administration module.

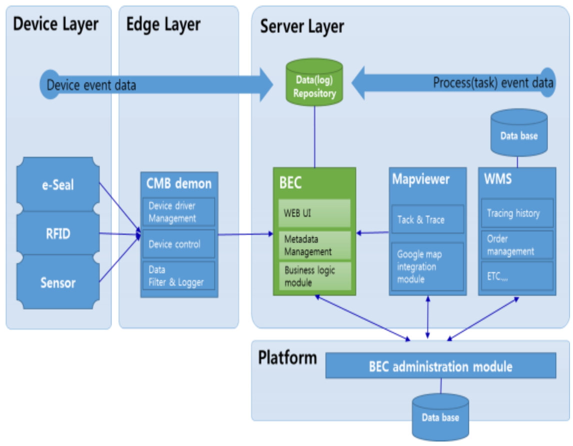

Figure 5. Main system configuration design

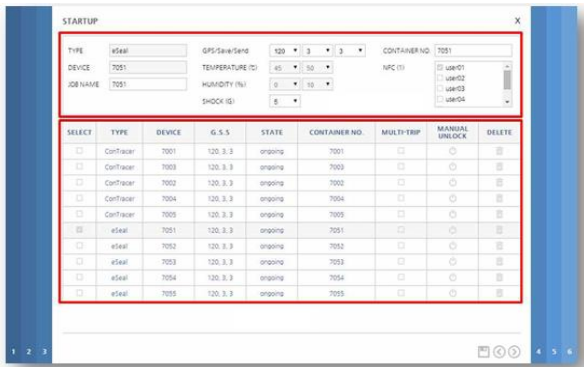

Figure 6. Campaign configuration steps on BEC software.

Fig. 6 shows campaign start-up configuration wide at which the eseal device is assigned to the container and the RFID card (driver) is assigned as well.

IV. Case Study

In order to test and evaluate the proposed asset tracking device, a set of experiments have been conducted that simulate various tracking scenarios and attempted breach. The test has been conducted in Goyang city, South Korea and it each test the device covered a distance from 5 – 7 km inside the city as shown in Figure 4 where the red dot indicated the location info transmitted to BEC from STAPID.

Before the asset is transported, it is movement path is geo-fenced so that an alert message is sent when the device leave the fence zone defined by the customer or system supervisor. The tracking process starts after locking the container at the source location. If the container is not locked, no trace data is sent from STAPID to BEC. The container can be unlocked by a special RFID tag provided to the truck driver or ship sailors. The location updates from STPID device are sent every 3 minutes and when a strong shock event is detected, the monitoring software displays a warning message at the control room. The triggering shock level and temperature/humidity ranges are set in the BEC server and they cannot be modified while STPID in operation.

Figure 7. Example of tracked container path

V. Conclusion

This paper presented a container tracking system based on WCDMA communication and RFID technology for securing containers and ensures seamless visibility of transported good along the supply chain. The proposed model composes of security device (STAPID) that acts also as a security lock for the container and it communicate the container status with a management server that oversees and control the device functionality. The proposed methodology is better than existing container tracking methods as it uses robust security mechanism (RFID) and communication protocol with wide data range (WCDMA). The presented case study also showed that the container status is updated rapidly (every 3 minutes) which help to quickly identify security breach and severe weather condition and act instantly to eliminate it.

Acknowledgement

This work is a part of the WCDMA based secure asset tracking project supported by National Program for Science, Technology and Innovation (NPSTI) from Saudi Arabia (project number 11-INF1713-10).

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