RFID Communication in Container Ports

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Abstract— Radio Frequency Identification (RFID) technology is gaining an increasing interest and becoming significantly critical in many industrial fields - including shipping and container ports. The latter are a natural place for the development of innovative cognitive solutions due to the complex processes and systems involving both human resources and artificial systems. The aim of this paper is to provide an overview of RFID's implementation in some selected container ports, and explain its strengths and weaknesses.

I. INTRODUCTION

Containerization has decoupled the production location of goods from their consumption markets thus helping in the globalization process. It has reached 100 percent for deep-sea general cargo transport in some routes between developed countries while it lies around 60 percent of all deep-sea transport [1]. Furthermore, the carriage of 90% of world trade is directly linked to the international shipping industry that deploys around 50,000 merchant ships every year to transport more than 6 billion tons of goods using some 20 million maritime containers [2]. This was possible thanks to lower transportation costs made possible by efficient container handling. However, there has been a tremendous pressure on ports and shipping industry generally to streamline the transportation processes, improve the quality, and cut costs in addition to handling security breaches especially under the last decade's terrorist threats. In the United States, the Container Security Initiative (CSI) entered in action in January 2002, followed by Customs-Trade Partnership Against Terrorism (C-TPAT) program in 2003. A third program, Operation Safe Commerce (OSC), administered by the Office of Domestic Preparedness saw the light in order to promote the development of smart containers, to increase the transparency of cargo, employ a high technology-based inspection, prevent cargo tampering, and reduce theft. While the two first programs target foreign ports and loading facilities in order to standardize the guidelines for securing container shipments, OSC tries to set the standards to be followed throughout transportation of cargo at U.S. ports. Moreover, a fourth program, the Port Security Act (PSA) of 2006, promotes among others the use of high technology to secure ports and cargo shipments. Use of cargo tracking, monitoring, and security technologies, such as sensors and seals, is encouraged [3]. In this context, RFID came to the rescue of ports and shipping industry and emerged as one of few technologies capable of dealing with these issues. RFID-enabled containerization can help comply with these regulations and enhance security and safety in international transshipment by ensuring the integrity of containers.

RFID is a promising technology that has been applied in many fields with relatively good success rate. However, there are some aspects that need to be addressed in order for it to live up to the industry's expectations. In this paper, first the concept of RFID will be defined, and then a glance at its fields of application will be given before we delve into its application in the context of shipping and container ports. The following section will be dedicated to a discussion of its limitations and challenges, and suggest some data mining techniques to handle RFID data sets. At last, a conclusion will summarize this work.

II. RFID TECHNOLOGY

The Association for Automatic Identification and Mobility (AAIM) defines Radio frequency identification system as "an automatic identification and data capture (AIDC) system comprised of one or more reader/interrogators and one or more transponders in which data transfer is achieved by means of suitably modulated inductive or radiating electromagnetic carriers" [4]. Simply put, RFID is an automatic identification and data capture technology that allows automatic wireless identification through a tag from a small chip to an RFID reader. Recently, it has become central in improving data handling processes [5] making them as automatic as possible by avoiding human intervention, thus eliminating human errors. It can be concluded from the automatic nature of RFID technology two direct benefits, namely, accurate and complete data collection and better utilization of employees' time [6]. While, the basic principle is similar to the one for barcodes, RFID chips are equipped with a microprocessor containing data memory space allowing them to be actual for a wider specter of applications [7]. The real advantage of RFID technology is its noncontact, non-line-of-sight reading, multiple reads at long ranges and high speeds (ca. 100 milliseconds), making it reliable in bad weather conditions for instance. It gives thus real-time monitoring and increases the security and visibility of the supply chain. However, to be functional, RFID technology requires a network of interrogators or readers and RFID tags. These tags can be either passive, read-only, or active that can actually send messages, thus requiring a battery. On the other hand and due to its read/write capability, the active RFID technology is suitable for some interactive tasks like maintenance or work-in-process monitoring. In 2010 a set of guidelines and specifications of the physical and performance capabilities and characteristics for EPC Gen 2 passive RFID tags to be used on containers that transport items via sea, rail, air, or road was published by GS1 EPCglobal's Transportation & Logistics Services Industry Action Group (TLS IAG). This report, called the Technical Implementation Guide for Conveyance Asset Tag (CAT) Environmental Testing, specifies the attributes, characteristics and performance capabilities that CAT tags must meet in order for each type of container and transportation modes. It directs as well how for tags to be attached and encoded. These guidelines are intended to be used for tag manufacturers and transport companies...
when testing and evaluating new tags, in order to increase their reliability for tracking freight [8]. RFID is compatible with the Global Positioning System (GPS) and Enterprise Resource Planning (ERP) thus it can use internet to achieve transparent and real time information flows [9].

RFID technology is so flexible that its application range is limited only by the lack of imagination and the market could grow exponentially. It is already applied in many fields with reported and documented success. It can be used among others in inventory and warehousing to avoid stock-outs or just to locate items or assets. In production, it can help retrieving the current stage of production for a given product. It can help crosschecking products received or to be sent against the actual order. In 2007 the Executive Vice President and CIO Wal-Mart Stores, Inc. Rollin Ford confirmed that among the benefits of using RFID are a 30 percent reduction of stock-outs, reduction of excess inventory in the supply chain, and sustainability impacts. He further explained that improving in-stocks for the customers avoids extra trips they may make to the stores. If having items in stock eliminates 100,000 extra trips, customers save up to $22.8 million per year only in gas consumption and reduce greenhouse gases by 80,209 metric tons [10]. This shows clearly the impact of RFID technology in retail business. In healthcare, it can be applied for newborn-infant tracking, as this is a sensible area. Tracking kids in an attraction park is another application of RFID technology where RFID bracelets worn by kids insure their position at any given time. In the US, it is used as well in toll road and in gasoline payment. Tracking of valuable and expensive assets, such as diamonds, art objects, and pharmaceutical products, is another field of application.

For automated plants or container ports, RFID can be used to give higher flexibility to Automatic guided vehicles (AGVs). Because traditional AGVs follow fixed predefined paths, readjusting the site or plant layout represents quite a challenge in itself. Thanks to RFID technology, this problem is solved, as the decision of AGVs routing will be based on real-time location detection resulting in simplified localization and collision avoidance systems [11], thus better overall performance.

In manufacturing, RFID tag information, combined with a data mining technology, was applied by [12] in the execution system for efficient process control (TFT LCD production line). Neural networks are used in estimate modeling while C4.5 algorithm is used to explain the estimate sequence supporting the shortcomings of neural networks algorithm. Together they helped find defective parts.

III. RFID APPLIED TO CONTAINER PORTS

The container transport has been growing annually with an average of 9.3% over the past decades increasing its modal share from 6.3% in 1980 to over 25% in 2007 [13]. While the world’s largest container ports can handle more than 25 million TEUs per year, only a mere 5% of the transported containers are physically inspected. Therefore, the risks of a container carrying illegal goods to pass through unnoticed are high. This is the reason back enforcing CSI, C-TPAT, OSC, and PSA regulations and container ports have not only to increase their operational efficiency but they must ensure the container integrity and participate in the visibility of their supply chain. Furthermore, there is a big pressure on governments to improve clearance speed, reduce costs and the administrative burden on international trade [2]. Thus, monitoring the movements of goods from the point of origin to the final destination becomes a requirement. To locate, retrieve and deliver containers inside a terminal can be prone of human error. Automating these tasks with the help of RFID-based systems will increase the accuracy of these operations reducing errors by as much as 70 percent [7], and thus help ports comply with all these regulations. Terminal operators develop better knowledge of the whole terminal through RFID technology, which improves the planning of terminal operations [7]. For instance, the transshipment time of a vessel in a port will be minimized, reducing thus the associated cost per container. Smart seals or e-seals (electronic seals) can best protect containers from tampering. They are RFID based smart seals, as can be seen in figure 1, and can be equipped with either a passive RFID tag or an active one. The latter enables intrusion detection or tampering and broadcasts real-time notifications while the former stores all the data to be discovered once the tag is interrogated. can as well be outfitted with RFID tags equipped with sensors monitoring several aspects such as the container's temperature, humidity level, change in the light, the level of radioactivity to name a few. Each container with an RFID tag has a unique identifier and can thus be easily found in the port's premises. In addition, the tag stores a lot of valuable data like the container's content, origin and loading date, and destination. These data can be communicated wirelessly to the port authority and the customers before arrival and the container manifest, the vessel's berth and stowage planning can be coordinated and generated automatically.

This means two things: first the speedup of customs inspection and clearance; and second that dynamic optimization of container operations is possible as RFID real-time data that was lacking before can now be collected. Therefore port operational efficiency will be enhanced [1]. As mentioned above, RFID technology make AGVs flexible thus increasing the overall performance. Furthermore, access to a port or to its sensitive areas can be granted through RFID-based ID badges. As a conclusion, container security and regulatory compliance, container identification, location and tracking, and access control are all areas where RFID technology can be implemented successfully in a port terminal. Moreover, RFID communication can be thought of as a cognitive infocommunications (CogInfoCom) system where the latter is an emerging research area defined as explores the relationship between the research fields of infocommunications and cognitive sciences, as well as the various engineering applications emanating

![An RFID-equipped smart container seal (© [7])](image-url)
from the synergetic combination of these sciences [14]. In
the context of container ports and following the
categorization made by [14], RFID can be classified as
inter-cognitive communication mode with a representation
bridging communication type since RFID makes
containers intelligent. In the following sections, the
deployment of RFID technology in some container ports
as well as some interesting projects is reviewed.

A. P&O Ports

P&O Ports decided to deploy RFID tracking technology
in their terminals worldwide while a joint venture in 2005,
called Savi Networks1, between port operator Hutchison
Port Holdings (HPH), operating at 39 ports around the
world, and Cargo-tracking provider Savi Technology [15]
was formed in order to track its customers' containers
worldwide. The technology used is based on RFID and
GPS technologies for containers, ships and trucks tracking
[16]. The concept is interesting as they are intending to
partner with ports; install their network and sell their
services to their customers similarly to telecommunication
providers the only difference is that the fee here is be
based per container trip.

B. The Port of Singapore (PSA)

The PSA Singapore Terminals handles circa one-fifth
of the world’s total container transshipment throughput
with a total of 27.1 million twenty-foot equivalent units
(TEUs) [17]. Due to the dynamic role played by the
government of Singapore in promoting RFID technology
allocating US$ 5.8 million for RFID research and training,
the port of Singapore became the first pilot port in Asia
under the U.S. Container Security Initiative in 2005 by
equipping all containers bound for U.S. seaports with
RFID seals [18]. A multi-dimensional grid in the port is
made of thousand of transponders incorporated into the
asphalt road of the shipyard [11]. Thus, the positioning
and location of containers can be accurately determined
based on the coordinates of the unique RFID transponders
and tags.

C. The Port of Busan

By 2005, the Port of Busan, South Korea deployed an
RFID container-tracking system in order to enhance the
security and operational efficiency of its container
terminal operations. This is in line with the South Korean
government strategy as the government is intending to
invest $18.6 billion over the next 10 years to improve the
efficiency and security of its global overseas shipping by
modernizing its ports. The Port of Busan is responsible of
81 percent of the nation's container cargo and 40 percent
of the national marine export cargo [19]. The deployed
system is a network composed of different types of
transponders, sensors (to check temperature, humidity,
light, container content…, etc.), seals and tags, mounted
on containers and cranes (only tags) from Savi's RFID-
based tracking technology. This system makes containers
smart and allows for tracking them and knowing their
exact position in real-time through a web browser as long
as it is on the port premises. This in turn helps port
management and scheduling tasks, thus increasing the
handling efficiency, which corresponds to increasing the
port's capacity. Another prototype project was carried at
the same port in 2006 by [20] where they designed and
implemented a smart tag system for IT-based port
logistics. This is an advanced project and the results were
satisfactory (high identification rate for multiple tags and
reliable energy budget). This system was based on active
RFID tags, electronic container seals, and RTLS (Real
Time Locating System) tags. Furthermore, it complies
with ISO/IEC and ANSI standards. However, some
limitations are to be signaled, namely the costs and the
interaction between the three components of this platform
should be optimized for it to be adopted by the industry.
Another issue is the handling of the massive data sets
generated by this system.

D. Rotterdam Port

The Port of Rotterdam had the world’s largest active
RFID installation implemented in 2005 by WhereNet
Corp.2 for the Broekman Group. The latter needed an
RFID-based real-time locating system for its over 250,000
vehicles at the port. Each vehicle is assigned a unique
identifier (Vehicle Identifier Number (VIN)) through its
active RFID-tag allowing the group to real-time monitor
its assets [21]. This resulted in an increased port
throughput, saving time and cutting costs, thus satisfied
customers. However the cost per RFID tag is not specified
to get a full picture.

E. The Ports of Long Beach, Los Angeles and South
California

The Port of Los Angeles and the Port of Long Beach
are the busiest and second busiest ports of United States
respectively. The Port of Los Angeles handled 8.4 million
TEUs in 2007 [15] while The Port of Long Beach had a
throughput of more than 7.31 million TEUs [22] the same
year. 2005 witnessed the deployment of an RFID-based
real-time locating system at The Port of Long Beach in
order to increase its efficiency. More than 90 percent of its
terminal operations were automated resulting in increased
door dock utilization, reduced yard congestion, and
increased throughput. This together with container tractor
drivers’ feedback resulted in a 50 percent reduction in
transaction completion time [7]. The number of trucks
entering the ports of Los Angeles and Long Beach is
increasing at a rate of 8 percent per year on average.
Therefore, driver security checks while decreasing
congestion is definitely a goal to be achieved. In 2007,
PierPass organization (created in 2005) consisting of 13
Southern California marine terminal operators required all
trucks using these ports to be equipped with 2.4 GHz
active RFID tags (WhereTag III transponder) from the
WhereNet provider [23] where the late version of these
tags (WhereTag IV transponder) is compliant with both
the ANSI 371.1 RTLS, the ISO 24730-2 RTLS and IEEE
802.11b Wi-Fi standards. The RFID tags were distributed
for free but each additional tag will cost trucking
companies about $50. The latter must register each truck
license plate number associated with the driver's license
number and the given tag in a database called eModal

1 the provider of the SaviTrak information service that
allows shippers, logistics and transportation companies to
manage and monitor their shipments over a secure web
connection: http://www.savinetworks.com/

2 http://www.wherenet.com/
maintained by a third party. This will expedite processing through the port's gate, thus avoiding a time consuming manual inspection; and in turn minimizing the trucks' idle time. This solution, combined with the incentives of using the ports in their off-peak periods, is accredited for congestion reduction and air quality improvement in the ports’ areas [22]. This program has been extended to both Tacoma port and to The nine container terminals of the port Oakland, namely, the Oakland International Container Terminal (OICT); APL; Ben E. Nutter; Outer Harbor; Charles P. Howard; Hanjin Terminal; Maersk Sealand; TransBay Container; and TraPac [24]. An RFID system, constituted of WhereNet active tags attached to cranes and other equipment, enables the tracking of which of these equipment and when that moved which container, thus allowing the company (APM) to pinpoint any given container’s status through tracking the equipment that transported it [25]. Furthermore, APM can determine exactly the location of the container on the dock thanks to GPS receivers, attached to container-handlerings equipment, together with location sensors fixed in 45 sections of the lot, which triangulate the RFID tags and send data to the server over an Ethernet connection [25]. By November 2008, the ports of Long Beach and Los Angeles engaged in the San Pedro Bay Ports Clean Air Action Plan where the target is to reduce truck-related air pollution by 80 percent by 2012. A subset of this plan is called the Clean Truck Program where pollution from all port-related sources must be reduced by at least 47 percent within the next five years. PortCheck, a new organization, was created in 2008 to achieve this goal using the same infrastructure laid out for the PierPass program. The same RFID tags already deployed for PierPass will be used and eModal will be readjusted to include the model year and type of engine of the registered trucks. This program will consist of penalizing trucks containing engines older than 1989 by paying a fee while trucks with diesel or alternative-fuel engines manufactured in 2007 or later will be exempted [26]. Clearly this system will yield some benefits both for terminal efficiency and environmental compliance. However, it is still at a testing phase and again, the cost of the RFID tags is quite high. On the other hand, the reuse of these tags from existing programs demonstrates the flexibility of this technology.

F. The Port of Hong Kong:

The port of Hong Kong has been the busiest container port in the world in 12 out of the 13-years period from 1992-2004 with a throughput over 20 million TEUs in 2004 [27] and 24 million TEUs in 2007 [28]. By late 2005, a joint venture of IBM and Maersk Logistics resulted in a development of a system for tracking shipping containers around the world. Instead of using 433 MHz RFID tags integrated with sensors and read by interrogators (readers) deployed at ports and other strategic points of the supply chain, this system goes beyond RFID technology and uses it just as a part of a collection of wireless technologies to transmit location and sensor data [30]. This system, called later the Secure Trade Lane (STL) solution, is using tracking devices called TRECs (Tamper-Resistant Embedded Controllers) which are small intelligent wireless monitoring boxes mounted on containers [2] and making them smarter. TRECs perform an automatic container events data collection including physical location based on GPS and state of the container (temperature, humidity, acceleration, door status., etc). TRECs’ communication can be achieved through communicate over a satellite, a cellular system (GSM/GPRS), or a Wireless Personal Area Network (WPAN) based on ZigBee3 /IEEE 802.15.4 radio. A handheld device can also communicate with the TRECs over a WPAN for the automatic creation of the container manifest, invoices, bills of lading, etc. The Shipment Information System (SIS), as shown in figure 2, ensures that the information provided by the TREC is available to the supply chain authorized actors with the appropriate information sharing among them as depicted in figure 3 [2]. This STL platform fully integrated SOA-based distributed network enables real-time access, tracking and monitoring of containers each participant with its authorized view, thus granting a full visibility of the supply chain from the manufacturer to the store. Furthermore, due to its versatility and the fact that it uses already-existing infrastructure, STL is relatively cost-effective and thanks to the collected data, supply chain processes, such as container port operations, can be further

G. The Port of Chennai:

The container freight station operator based in Chennai India, A.S. Shipping Agencies, is mixing both RFID with GPS/ GPRS technologies in order to track containers throughout its 24.3 hectares yard, situated 16 kilometers away from the Port of Chennai. Ultrahigh-frequency (UHF) RFID interrogators (compliant with the EPC Gen 2 standard), antennas, and GPS receivers are fixed on cranes. Once a container arrives at the storage yard, it is weighed and, by means of a small touch-screen device, the crane operator enters its information into the system. Then, a passive RFID tag is linked with the container number and mounted on the top of the container. The tag data is updated with the GPS latitude and longitude information, and then conveyed via GPRS to a central server database. The container’s location is then visualized on a Web application. The container location is thus updated automatically as the container moves through the yard area [29]. The main advantages of this system are the clear reduction in container location time in the yard from up to 24 hours to 2 to 5 minutes, better yard capacity planning and accurate customer billing knowing the exact storage time. Moreover, container information can be accessed, through a Web application, by clients anywhere in the world. All these factors increase the service level provided by the company. However, this system still need to be integrated with the company’s billing system [29].

H. IBM & Maersk:

In 2005, a joint venture of IBM and Maersk Logistics resulted in a development of a system for tracking shipping containers around the world. Instead of using 433 MHz RFID tags integrated with sensors and read by interrogators (readers) deployed at ports and other strategic points of the supply chain, this system goes beyond RFID technology and uses it just as a part of a collection of wireless technologies to transmit location and sensor data [30]. This system, called later the Secure Trade Lane (STL) solution, is using tracking devices called TRECs (Tamper-Resistant Embedded Controllers) which are small intelligent wireless monitoring boxes mounted on containers [2] and making them smarter. TRECs perform an automatic container events data collection including physical location based on GPS and state of the container (temperature, humidity, acceleration, door status., etc). TRECs’ communication can be achieved through communicate over a satellite, a cellular system (GSM/GPRS), or a Wireless Personal Area Network (WPAN) based on ZigBee3 /IEEE 802.15.4 radio. A handheld device can also communicate with the TRECs over a WPAN for the automatic creation of the container manifest, invoices, bills of lading, etc. The Shipment Information System (SIS), as shown in figure 2, ensures that the information provided by the TREC is available to the supply chain authorized actors with the appropriate information sharing among them as depicted in figure 3 [2]. This STL platform fully integrated SOA-based distributed network enables real-time access, tracking and monitoring of containers each participant with its authorized view, thus granting a full visibility of the supply chain from the manufacturer to the store. Furthermore, due to its versatility and the fact that it uses already-existing infrastructure, STL is relatively cost-effective and thanks to the collected data, supply chain processes, such as container port operations, can be further

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4 Service-Oriented Architecture-based network
streamlined, cutting costs, improving quality, safety, security and making happier customers.

Trials have been made of this platform and today; the STL solution is at the focus of a large-scale international research project called Information Technology for Analysis and Intelligent Design for e-Government (ITAIIDE). The aim of this project, sponsored by the EU, is to define and use the STL solution in order to make international trade safer while optimizing the administrative processes.

![Figure 2. Shipment Information System (SIS) (© [2])](image)

RFID technology has proven to be crucial in improving container operations efficiency, the security of the port, and in tracking containers, enhancing thus the visibility of the supply chain. However, the RFID reading infrastructure represents the most extensive share of all investments, e.g. in e-seals. Who should pay for what is still an open question [31]. Poor return on investment can be deduced from the RFID publicized cases. There is a lack of research into the adoptions of RFID technology as well. This has left organizations in doubt whether to adopt it or not [32]. For instance, in South African container ports, the costs and the complexity of implementation of RFID systems were the main hinders to RFID adoption. This was accompanied with a poor understanding of its benefits to the overall supply chain [32]. Therefore cost structure is deterrent for small and midsize ports to implement this technology to its full potential and it seems that its usage is more appropriate for ports with high throughput. However, the industry is going in the right direction cutting cost and improving the return on investment. This fact has thus made it profitable for midsize ports to invest in RFID systems [33]. Another issue is standardization as there are several standards operating simultaneously in the industry. This problem can be partially solved by market forces but IMO (International Maritime Organization), ISO (International Standards Organization), WCO (World Customs Organization), and governments should take a lead in order for it to unify these standards into one complete unanimously adopted standard which will reduce the costs and boost the adoption of RFID technology. The massive data generated from RFID systems is a challenge in itself and the way to deal with all these collected data is still an issue. The use of encapsulation and decentralization combined with the ontology concept can be a solution. Another straight forward way can be the use of data mining and soft computing techniques. However, in order to enhance supply chain visibility, RFID technology should be integrated with supply chain informational, decision oriented or transactional technologies [34]. As RFID infrastructure is expensive, the best solution for container ports and maritime supply chains will be constituted of hybrid systems where already existing infrastructures will be exploited together with RFID, GPS and other technologies.

![Figure 3. An SOA-based distributed network enabling end-to-end data collection and reporting (© [2])](image)

**IV. DISCUSSION**

A summary of port RFID implementation from the precedent section is presented in Table I below. One can notice many interesting aspects. First, most of these initiatives started between 2005 and 2006 meaning that the markets of container ports, shipping and logistics providers matured and started investing in RFID technology in this period of time. Second, there are two different alternative deployed solutions, either direct investor and solution owner or user of a service similar to telecom services where the fee is based per container trip as implemented by P&O in 39 ports around the globe. Third, the majority of container terminals opted for the use of active RFID tags, something that can be explained by their mega size, thus a fast return on investment. Last, RFID systems are not used alone but rather combined with other technologies in order to offer the desired outcome. Here, the IBM/ Maersk solution seems to integrate RFID together with an anthology of other technologies.

Since each monitored container generates the history of all the locations it occupied through time, the generated data from a representative RFID application will be massive. Therefore, special methods and techniques are required, to warehouse, clean and deal with RFID data. When it comes to cleaning RFID data sets, traditional cleaning techniques use accurate methods that perform well but at a high cost. To circumvent this, a collection of cleaning methods with associated costs, where the expensive methods are used only when necessary [35], should be used. As for warehousing, an efficient model that preserves object transitions while providing significant compression and path-dependent aggregates is used but under the condition that at early stages items usually move together in large groups such as containers in a vessel.
TABLE 1. SUMMARY OF RFID IMPLEMENTATIONS CHARACTERISTICS IN DIFFERENT PORTS

<table>
<thead>
<tr>
<th>Port/Project</th>
<th>RFID Technology</th>
<th>RTLS</th>
<th>GPS/GPRS</th>
<th>e-seals</th>
<th>Sensors</th>
<th>Others</th>
<th>Standards</th>
<th>Year</th>
<th>Remarks</th>
</tr>
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<tr>
<td>P&amp;O 39 Ports</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2005</td>
<td>Services to customers similarly to telecommunication providers. The fee is based per container trip.</td>
</tr>
<tr>
<td>PSA</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2005</td>
<td>Transponders grid</td>
</tr>
<tr>
<td>Busan</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>Rotterdam</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>2005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA/Long Beach</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>2006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oakland</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2006</td>
<td></td>
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<tr>
<td>Tacoma</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>2006</td>
<td></td>
<td>DTTN networks</td>
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<tr>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2006</td>
<td></td>
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<tr>
<td>Chennai</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM/Maersk</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2005</td>
<td>SIS, STL, TREC’s, etc.</td>
<td></td>
</tr>
</tbody>
</table>

This model is made of a hierarchy of highly compact summaries (RFID-Cuboids) that enable the discovery of trends in the movement of items at different abstraction levels and provides user-defined views of the data [36].

However, efficient methods for outlier detection, path clustering, and other data mining problems are open for further research. Here we argue that the use of association rules mining will be appropriate. Association rules are a form of local-pattern discovery in unsupervised learning systems [37]. They are also known as Generalized Rule Induction, and aim to find any rules of interest that can be derived from a data set (mostly If...Then ...rules) [38].

Association rules mining seeks to extract interesting correlations, frequent patterns, associations or causal structure with a minimum support in a data set [39]. It is based on a association rules discovery algorithm called Apriori. Apriori is a seminal algorithm proposed by Agrawal R. and Srikant in 1994 for mining frequent itemsets for association rules using prior knowledge of frequent itemset properties [40]. It finds the frequent itemsets in the database through several iterations. Iteration i computes all frequent i-itemsets (itemsets with i elements) where each iteration is composed of two steps: candidate generation and candidate counting and selection. However, a more computationally efficient algorithm is based on partition principle. This partition-based Apriori is efficient as it only requires two scans of the transaction database [37].

Association rules mining was deployed successfully in many fields such as customer satisfaction, improving product port-folio identification, quality improvement, manufacturing defect detection, improving the quality of assembly operations to name a few [39]. Due to its simplicity, efficiency and versatility, association rules mining will surely lend itself to yield satisfactory results with RFID applications. Kiziltoprak et al. look at the problem of dealing with the massive data generated from IT and logistics systems. They asserted that the level of automation of data collection must be increased while information overflow must be avoided. In addition to data mining, the best way to handle these generated data is through encapsulation and decentralization by using semantic enriched standardized communication through concepts such as Web Services and Ontology. They focus on container ports as they are the supply chain's bottleneck. Their goal is to enable a distributed container handling approach with proactive containers where these smart containers are capable of wirelessly registering themselves and interacting with their environment and between each other. The technological platform supporting this work is based on ZigBee and LEACH (Low Energy Adaptive Clustering Hierarchy) routing protocol to build up the network and develop a software platform as a SOA based on the UPC UA5 Architecture and using OSGi6 as the framework [41]. A similar research project is carried out by SFB637 but the focus is rather on the entire transportation chain [42]. These two projects go in the same direction as the IBM/Maersk project. These three solutions together with Savi Networks alternatives constitute, in our opinion, competing and/or complementary solutions for the future. The RTLS market is expected to jump from $30 million in 2005 to $2.71 billion in 2016, as reported by IDTechEx, a research and consulting firm focusing on RFID [43].

V. CONCLUSION

RFID-based containerization has changed dramatically the landscape of ports as it improved the visibility of containers and container operations resulting in better security, better safety, improved quality, reduced cost, reduced emissions, high level of service, and ultimately satisfied customers. RFID technology can be used efficiently in container ports to improve container security and regulatory compliance, container identification, location and tracking, and access control. Human errors can be reduced by up to 70 percent and in-port transaction completion time by up to 50 percent. RFID real-time data make it possible for AGVs to be more flexible by postponing the routing decision, and it allows for dynamic optimization yielding better planning, higher efficiency and overall performance as a whole. An important advantage is that it enables dynamic optimization in container ports, a much needed tool for solving increasingly complex problems. The high level of flexibility and dynamic optimization allow the achievement of real time solutions that could not been obtained nor reached otherwise. Therefore RFID technology can be considered as an appropriate CogInfoCom system. However, there are some drawbacks

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5 A client-server standard for communicating process information with the Unified Architecture
6 The Dynamic Module System for Java™
with RFID technology. For instance, the infrastructure is a high binding investment making it accessible mostly to big ports and to a certain extent to midsize ports while small ones are still reluctant the cost is prohibitive towards adopting it. Another issue is developing unified RFID standards that will greatly simplify this technology and its accessibility. However, there is a tendency toward standardization as can be seen from the different implementations discussed in previous sections. Both cost reduction and standardization could be managed by market forces but governments, IMO, ISO and WCO organizations should grab this opportunity to shape tomorrow’s solutions. A third problem is the massive RFID generated data sets. Here, cost-aware cleaning methods, RFID-cuboids for warehousing combined with association rules for data mining can be appropriate. Many of the world leading container ports have in fact implemented RFID technology opening the way for several different RFID system configurations. Among these, some need to be mentioned, namely projects that go beyond container port coverage and deal with the whole supply chain from the point of origin to the final destination. Moreover, RFID is used just as a component in a collection of technologies. These solutions can be marketed either as a direct investment or as a purchased service (similar to telecom) where the fee is a trip per container. Whatever the future brings for container ports, one thing is sure; RFID will be an integrated part of their core technology.

REFERENCES


