RFID Infrastructure for Large Scale Supply Chains Involving Small and Medium Enterprises

John P.T. Mo and William Lorchirachoonkul
RMIT University
Australia

1. Introduction

A "manufacturing based supply chain" containing a broad spectrum of partners, including manufacturers, third party logistic providers, distributors and retailers, all of whom, have mixed modes of value adding processes (Chauhan & Proth, 2005). An important success factor for this type of supply chains is the ability for the partners to identify and track products moving through the supply chain, using the latest information technologies (IT). However, these value enhancements would vary substantially according to the nature of the partners' business requirement. As such, the flexibility of managing the IT infrastructure for supporting value adding activities is of the utmost importance.

Radio Frequency Identification (RFID) is a wireless communication technology for precisely identifying objects. It uses radio-frequency waves to identifying information between tagged objects and readers without line of sight, thus enabling automatic tracking and tracing. Passive RFID can track products in supply chains from the supplier to the distribution centre, warehouse, and point of sale. RFID technology is increasingly used in supply chain management (SCM). However, like most emerging technologies there are different vendors, standards, systems, applications, appliances and processes that exist today. Therefore, potential increase in productivity is heavily offset by huge capital expenses on assets which may be obsolete in a few months' time. As a consequence, most small and medium enterprises (SMEs) simply wait until such time that they feel the technology is mature and stable enough to be integrated into their existing operations.

Traditionally, supply chain network is built on existing IT infrastructure of the companies involved in the supply chain. Since major companies have IT policies that naturally channel data in a global fixed network structure, the supply chain information backbone is built based on the assumption that communication will be directed to the Internet. Typical examples are the two Australian national scale projects that were supported by the Australian government to investigate the properties and limitations of electronic product code (EPC) technology for fast moving consumer goods (FMCG) supply chains (Mo et al, 2009b). In Europe, the project "Building Radio frequency IDentification solutions for the Global Environment" (BRIDGE) was supported by the European Community sixth framework programme to resolve the barriers to the implementation of the EPCglobal Network in Europe (Soppera et al, 2007). The BRIDGE project aimed to develop easy-to-use technological solutions for the European business communities, including the SMEs. These

Source: Sustainable Radio Frequency Identification Solutions, Book edited by: Cristina Turcu,
ISBN 978-953-7619-74-9, pp. 356, February 2010, INTECH, Croatia, downloaded from SCIYO.COM

projects show that the application of EPC technology can lead to significant benefits in system efficiency and reliability. Ironically, large organisations, which already embrace RFID technology, will often need to communicate with SMEs that may not choose to implement RFID due to resource constraints. Under these circumstances, there is no other physical way in that the RFID tags can be read or updated in some parts of the supply chain, the entire information link is disrupted.

One of the ways to resolve such issue is by the method of virtualisation. Virtualization implies the utilisation of IT and communication technology by the business organizations to manage their key operations with stakeholders, such as customers, suppliers and employees (Demchenko, 2004). Virtualisation is to encapsulate a physical device to behave as multiple virtual devices where the resources of the physical device are shared among the virtual devices. Most of the existing frameworks are based upon physical RFID tags being read by RFID readers which reside over a gate or doorway. As products containing RFID tags move across the RFID readers, the location of the products is confirmed. This feature may be very useful for traceability in a warehouse operation environment, but it may not be necessary when products move across two trading parties. Since the objective of the RFID reader is to verify that the product has arrived at the receiving party, the sending party does not require extensive and details of information, for example, which door or gate their product are received. The main objective is to verify that it has been received. Therefore, if the RFID readers themselves can be emulated or have virtual machine build-in, the implementation and maintenance process would be more efficient and the overall costs of ownership reduced.

In this chapter, we review the lessons learnt from the two national projects in Australia. We examine the activities in the projects by modelling and simulating them in a discrete event simulation environment. The outcome is an estimation of the benefits that can be derived from the national projects if it was continued for a much longer period. We then discuss a virtualisation model which incorporates existing RFID framework based on the EPC Network for application in large scale supply chains. The model allows alternative technologies to verify the position of the RFID tags and then updates the existing RFID framework to ensure that the traceability of the RFID tags remain intact, even if there is an interruption in data along sections in the supply chain. With these new developments, a mixed mode value added supply chain will be able to include any members in the supply chain, large and small, without the concern of information infrastructure incompatibility.

2. RFID pilot projects

In a typical deployment, RFID tags are affixed to individual products, and readers installed at various checkpoints capturing tag-reading events. Companies then transport these tagged items along the supply chain, leaving trails of tag-reading events behind. These events enable the companies to record product movement in the supply chain. Unfortunately, passive RFID technology has limitations, both in terms of physical constraints placed on signal transmissions and how much data a tag is able to store. To access more data about a product (such as its production date, batch number, or package size), organizations could store most of that information externally in a central data warehouse and use the RFID tag as a key. All organizations would have to agree on a common storage format and continuously upload their data to the central data warehouse. This approach has several severe drawbacks, for example competing. Competing enterprises are often reluctant to put their data in a shared central database.

To explore the functionality requirements associated with large-scale RFID applications, two Australian RFID national projects were developed. The projects were conducted in real industrial environments integrating the experimental investigation with normal business operations between industry partners in two cities, Melbourne and Sydney.

2.1 The national EPC network demonstrator project

The EPCglobal Network standard provides a promising architecture for tracking and tracing objects over the Internet (EPCglobal, 2006). However, few real-world large-scale application examples were reported. Consequently, practitioners lack guidance and only have their own limited deployment experience from which to learn. To gain first-hand, practical experience the National EPC Network Demonstrator Project (NDP) aimed to identify the business benefits of sharing information securely using the EPC Network, providing authentication to interacting parties, and enhancing the ability to track and trace movement of goods within the entire supply chain involving transactions among multiple enterprises. The key concepts in the NDP include:

- using the EPCglobal Network standard,
- providing authentication to interacting parties, and
- enhancing organizations' ability to track and trace product movement within the entire supply chain and for transactions among multiple enterprises.

This project was the first in the world to demonstrate the full stack of the EPC network architecture enabling inter-organisational transactions and supply chain management. When a given tag was detected, instead of having each company storing this information and communicating to the next partner, the EPCglobal model defined one authoritative registry of numbers that could be queried for links to access detail information from local servers. Hence, all items to be identified were allocated a unique global EPC by GS1. Items of interests included products (identified by a serial GTIN - SGTIN), pallets (identified by a Global Returnable Asset Identifier - GRAI), and unit loads (identified by a Serial Shipping Container Codes - SSCC).

The NDP was a large scale project, involving 13 consortium members. To ensure a good chance of success, the consortium simplified the material flow process by limiting to 9 product items. The system designs were incorporated in 15 use cases developed by the industry partners of the consortium. Use cases are the description of how the business processes work with the system (software). Several innovative process designs were developed to support data integrity of the system (Mo, 2008a).

In order to share information securely among the partners, the NDP web site was set up on a global server. Partners could access the web site using a username and password pair control. Once logged in, the product information, containment (content), history (track and trace) information can be accessed using the EPC as the search key (Figure 1). This data sharing capability was the biggest advantage of the NDP which demonstrated the data transparency about the traded items. Detailed transaction data such as location and time about an item (e.g. a shipment on pallet) were immediately available to other partners once the information was logged to the global EPC information server. The timely information improved the efficiency of the supply chain.

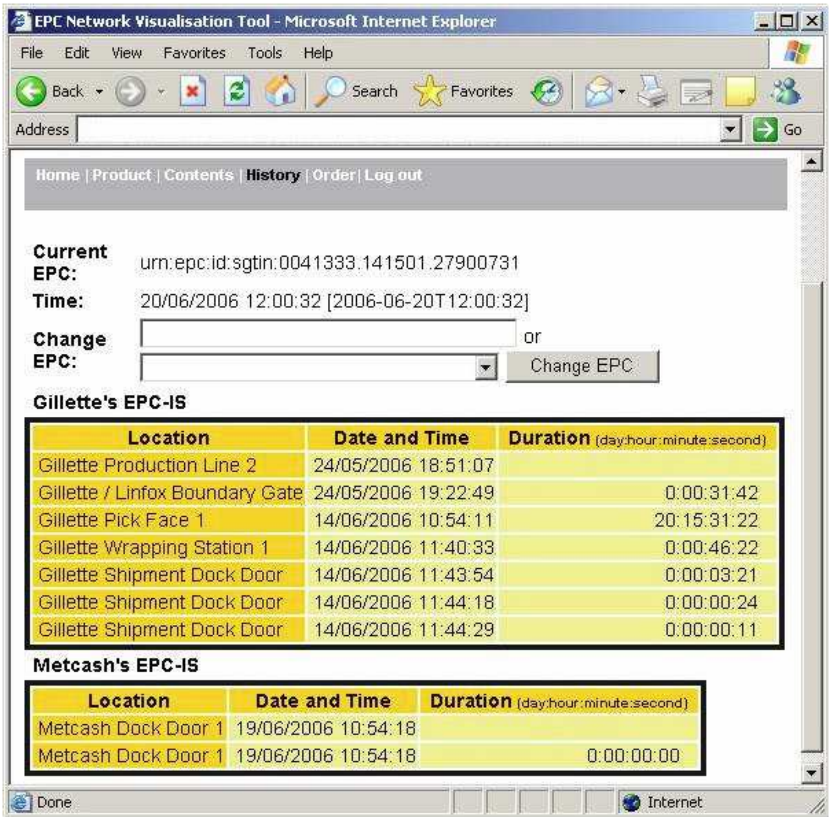

Fig. 1. Track and trace for item urn:epc:id:sgtin:0041333.141501.27900731

2.2 The NDP extension

Following the NDP, some of the partners continued the research and re-grouped as a second consortium working on an extension project "National EPC Network Demonstration Business Information Integration" (NDP Extension) (Mo et al, 2009a). The NDP Extension aimed to address the industry's expectation to see RFID building into real processes and integrating the data with business information system. The NDP Extension concentrated on assets, in this case pallets. Asset management was one of the potential benefit areas identified in the NDP.

Management of assets throughout the supply chain was an onerous and surprisingly complex task. As assets moved between trading partners, irregularities were hard to spot at the time. Errors in quantities sent and received was not spotted until the statement was available, which could be several weeks later. The discrepancy then had to be negotiated between trading partners, each of whom had their own version of events and supporting paperwork that may be in conflict. Since there were more than 10 million pallets in circulation throughout Australia, the effort spent managing assets was extremely costly.

The NDP Extension provided an industrial environment to test the EPC Network technology for solving the asset management problem. Six sites, three in New South Wales and three in Victoria were installed with the EPC hardware and network infrastructure. The project had the advantage to use the latest RFID hardware so a high read rate in the system was anticipated.

Some problems were reported. Initially test runs were unsatisfactory because the readers were unstable in detecting the RFID tags passing through their RF fields. As more tests were done, it was found that there were quality problems of the tags. Some tags were coded incorrectly. Some tags had manufactured problem that they were inherently weaker tags. Since the consortium used 3 different brands of readers, there were also site and reader specific issues. These problems were rectified by a number of remedial measures. Each reader was tested thoroughly as a standalone unit as well as when it was connected to the EPC Network. Tags were individually checked before used.

The consortium was able to perform 4 paperless test runs of pallet despatch and delivery transactions for each site. The test runs proved that business information integration for supporting paperless delivery of pallets could be practised provided that 100% read rate was achieved in the transaction. Process models were developed for each of the transaction routes and benefits were reported as shown in Table 1 (Gajzer, 2007).

Company	Labour cost $/hr	Standard Time min/ delivery	EPC Process Time min/ delivery	Increased Efficiency %
CHEP Erskine Park	$32	35	23	34.3%
Masterfoods	$28	35	30	14.3%
Linfox	$25	38	36	5.3%
Acco	$23	35	30	14.3%
Westgate Logistics	$31	45	35	22.2%
Average				18.1%

Table 1. EPC process efficiency gain

The efficiency gain and hence cost reduction due to the elimination of data entry, verification and reconciliation processes was significant, especially for the pallet supplier. Furthermore, improvement in inventory accuracy as well as improvement in quality area, such as accuracy and transparency of information and real time processing had great impact on the other logistics operations such as planning and forecasting.

In addition, the project developed a business scenario in which the EPC Network could be provided to the general public as a subscribed managed service. The normal business model was that for any company to implement EPC Network, the company had to invest significant amount of resources at the start. The investment includes cost of IT infrastructure, tagging process, training, fault tolerant systems and others. This was the capital expenditure model. The new subscribed service had the potential to change it as an operating expenditure.

2.3 Key features of NDP and its extension

The distance between transaction locations was a significant factor, causing undesirable delays in the system's ability to complete transactions or provide visibility for the items in transition. The various NDP partners jointly developed the system to support these transactions. The system must maintain consistency across physical and organizational boundaries. The partners adopted a six-layer model (Figure 2), from the EPCglobal architecture, which specified the top three layers. The partners developed the operational elements that span layers 4, 5 and 6:

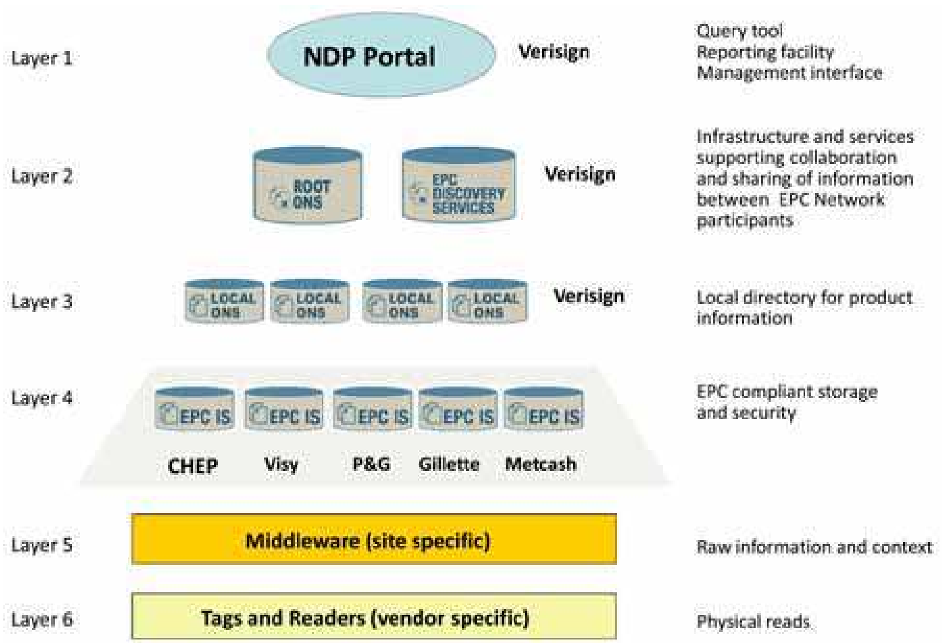

Fig. 2. The NDP layered architecture.

- *NDP portal.* The consortium developed the portal to display the data collected and stored in the system and to allow companies to query the movement of goods through the supply chain.
- *Root objects name service (ONS) and discovery service.* The ONS identifies unique numbers for manufacturers, whereas the discovery service points to a particular EPC information service (EPC-IS) in which companies can obtain detailed information on a specific item.
- *Local ONS.* Each industry partner maintains its own repository of product-specific data. The local ONS provides a pointer to the local database.
- *EPC-IS.* At each site, the industry partners maintain details about site-specific product data that other participants can query.
- *Middleware.* An onsite software component converts multiple reads to one read, adds contextual information (such as the reading location and timestamp), and formats data for storage in an EPC-IS.
- *Tags and readers.* Physical reads capture RF signals in the form of hexadecimal numbers and transmit them to the server for the middleware layer to filter.

In Figure 2, VeriSign implemented the first three layers. While the rest of the EPC Network were implemented by partners involved in the NDP. Adopting a common architecture solved half the visibility problems. However, partners still had their own internal systems and processes that weren't compatible for information exchange.

3. Analysis of the national projects

EPC technology is designed on the premise that a supply chain network is built on the existing IT infrastructure of the companies involved in the supply chain (Kelepouris et al, 2007). However, if one of the participants is not EPC compliant, the information link for the entire supply chain can be disrupted. Capital expenditures are limited. It would be difficult to convince these companies to invest in new technology infrastructures such as EPC. The common concern is that the technology is unstable and not mature enough to remain an industry standard. With rapid advances in technological progress, the current technology may soon be obsolete. Moreover, the costs of training and implementing such technologies are high, thus putting further pressure on already narrow profit margins. To assist decision making for companies in a supply chain, the NDP and its Extension are analysed by two methods.

3.1 Modelling and simulation

This research has been analysed by digital simulation. The computational logic of the simulation model is based on the work flow and information flow of the NDP processes (Mo, 2008b). At the beginning of each day, Metcash DC checks inventory to decide whether to place an order. If the inventory level is less than a pre-defined level, Metcash DC orders replenishment up to certain level. Figure 3 shows part of the work flow in the NDP simulation model.

Metcash's purchase order initiates most activities at P&G, Gillette CHEP and Visy. Only Gillette Manufacturing is independent from Metcash's purchase. Gillette Manufacturing's activities are based on the sales forecast and the production quantity will be based on the purchase order quantity rather than inventory. The NDP simulation model is further separated into five sub models. Each sub model represents a consortium member and has several functions for different work.

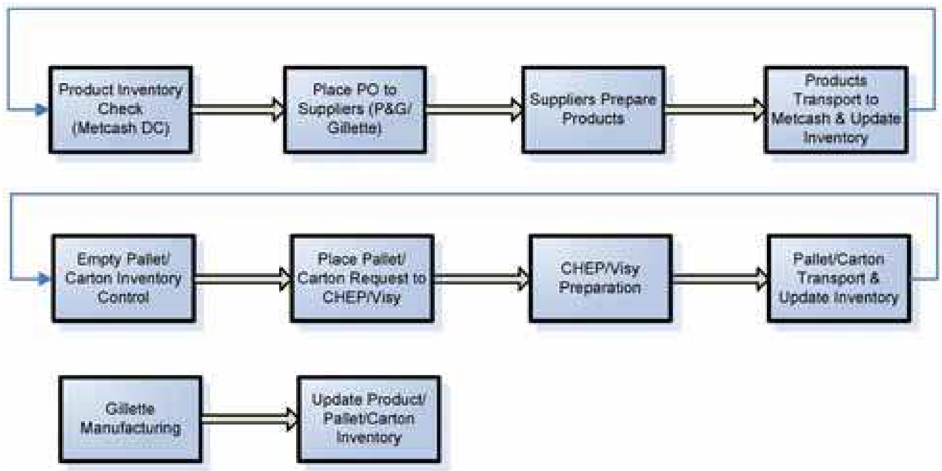

Fig. 3. Basic work flow in NDP simulation model

By running the simulation model, it was found that a saving of $192,158 on overall labour cost can be achieved if the NDP continues for a year. Other costs such as overhead and materials costs are not included. Therefore, it only represents a tiny section of the potential savings of the supply chain. Given that there are thousands of products handled by the consortium companies, the savings will be significant if the EPC technology is rolled out to the whole supply chain.

3.2 Network compatibility

A stable and reliable network and IT infrastructures of value added supply chain is vital for both of the national projects in Australia. To ensure such stability and reliability, each partner maintain their own EPC information server (EPC-IS), behind their firewall (Figure 4). It's common for large scale operators to host their network equipments and IT infrastructures at a data centre. These provide additional layer of redundancy for back up data. Should the power shortage occur, secondary and tertiary back up power supply will be activated? Data centres will also provide regulated temperature and humidity control, such that these equipments work at optimal operating condition. Such facilities are expensive, and may not be an affordable option for smaller organisations.

In order to maintain the speed and reliability of the information transfer between the RFID reader, the middleware and the EPC-IS, the quality of the link between sites must be of high standard. However, it may not be cost effective to to establish such wide area network (WAN) connection. In some remote sites, where the land value is lower for new warehouse to be built, the link may not be possible due to lack of infrastructures. The Australian and European projects used connections in established areas, where the network has been operating in an ideal optimised condition. In addition, the RFID gates were considered a fixed asset in the two national projects. Each member in the consortium used their own RFID readers which were assigned to their specified location. However, in the 3PL environment, where a single warehouse location can be used to represent different suppliers and customers, the RFID readers cannot be modelled as fixed assets and are only updated by a single EPC-IS which belongs to a single entity. After the tags are read and filtered by the middleware, it will still need to be managed by an intelligent decision system that ultimately routes the information to the correct EPC-IS. The information is then translated to a meaningful business function and process.

As shown in Figure 4, an EPC Network supports access to EPC portals. Queries to the ONS server which ultimately points to an EPC-IS that stores the database behind each organisation's firewall. Similarly a decision system is also needed to do similar query as those of the EPC portals. A set of queries can be sent to multiple EPC-IS at the same time to query an order that consists of multiple tags. However, if one of the links is broken (due to system response, connectivity, security or other reasons), that request may not be executed. If the result of that particular query is required to trigger an event or change of ownership, failure of transaction may occur. Moreover, a gap exists between those supply chain members who are fully EPC compliance and those who do not have such network infrastructure in place. Although EPCglobal has published a universal EPC standard, individual countries are still free to impose further restrictions to the frequency band and power ratings that EPC devices can be used on their land. EPCglobal has been widely used amongst European and western countries. However, there are other RFID frameworks being utilised around the world. These include China's National Product Codes (NPC) (more information can be found at http://www.chinapt.com/CptNpc/En/Npc_e.aspx) and Japan's Ubiquitous ID (UID) (more information can be found at http://www.uidcenter.org/english/introduction.html), which is supported by 352 Japanese companies including Sony, Toyota, and Mitsubishi. These networks operate under different radio frequencies and have different structure to those of EPCglobal. As China is now the world largest exporter, it is important to acknowledge their views on the technology. In order for the tags to be read successfully across the supply chain, a system that is flexible to handle a wide variety of operating parameters (within the universal standards) is mandatory.

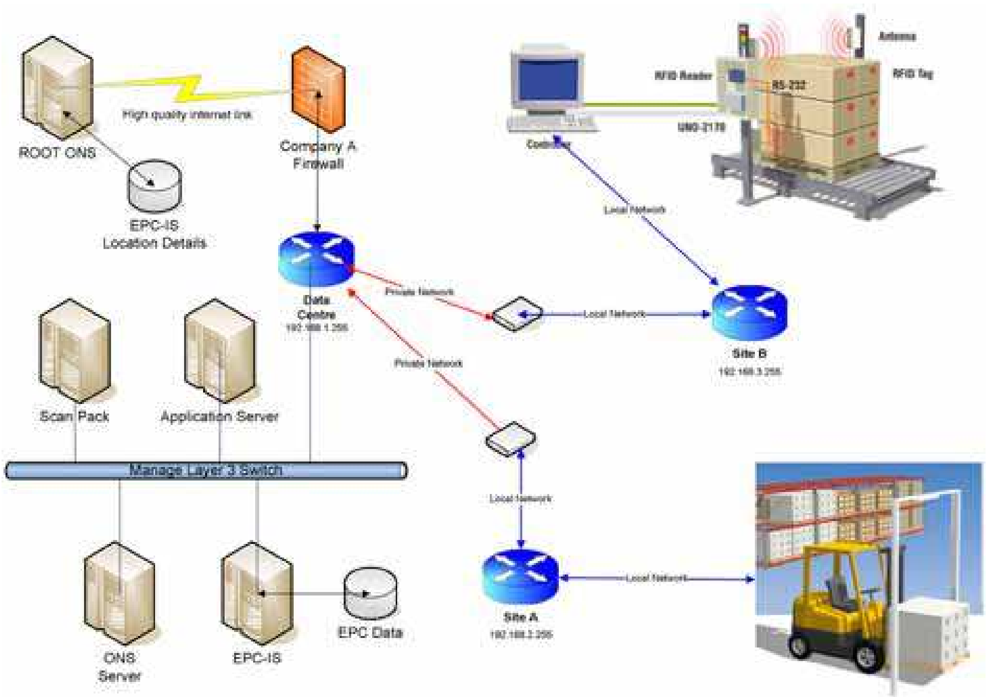

Fig. 4. EPC Based System Architecture

4. Virtual network infrastructure

Virtualised IT environments have been developed to reduce costs and improve reliability (Liu et al, 2008). Virtualization implies the use of IT and communication technology by organizations in managing their interactions and key business operations with stakeholders, such as customers, suppliers and employees (Zarour et al, 2005). In a virtualized environment, the virtual devices are seen externally as handling different functions. Such virtualisation techniques have been used in medium to large scale information technology infrastructures, where vendor such as VMware, Citrix Xen Server and Microsoft Hyper V use a single physical server to host many virtual servers that perform a range of tasks (Kim, 2008). It uses the concept of Hardware Abstract Layer (HAL) which is presented to the operating system in each virtual server as its usual hardware platform. Therefore, a virtual machine can be moved to and from different physical servers with different physical configurations and vendors. By simplifying the hardware and hence reducing the cost of

new system implementation, it is then possible to increase the redundancy of the system or reduce power consumption with less physical hosts.
Virtualisation of supply chain systems depend on the use of the Internet. In a network environment, hierarchical virtualization of a network provides a flexible, granular, protection resource. Using the HAL concept, the network services are handled by a number of virtual servers. In the event that a physical server hosting the virtual servers fails, another physical server with the virtual systems (potentially another server already operating on the network) can stand in as an alternative physical host. This improves the robustness of the system in operational functions and data backup. Since supply chain participation is a loosely coupled relationship, increased mobility of information infrastructure will significantly improve the efficiency of supply chain system set-ups and encourage cost effective partnering relationships.
To develop a virtualised RFID infrastructure, it is necessary to use alternative technologies that function as RFID in the absence of RFID. Since RFID is relative expensive to established, establish, we cannot assume that all SME can afford to implement and maintain such technologies. SME who do not subscribe to RFID network, are not visible to the rest of the RFID subscriber, hence, creating a broken chain to the global supply chain. For this reason, we cannot afford to have a complete reliance on a single technology to drive a global supply chain network.

4.1 GPS

The issue of high infrastructure cost for RFID implementation has attracted serious questions with respect to its suitability for the supply chain industries, as many are SMEs. (Pedro & Reyes, 2007). Alternative technologies are being investigated, one of which is global positioning system (GPS). Since late 1990's, it has been a common trend for third party logistics (3PL) companies to incorporate GPS technologies via mobile data networks such as GSM or GPRS to track vehicles and drivers (Zito et al, 1995). The key function for such technology is to provide accountability and traceability to the end customer, especially when billing on an hourly basis (taxi truck, over dimension freight). It is also used in reverse, for checking subcontractor invoices and accounting for the time charged (Hamilton, 1993).
GPS has been utilised in most Fleet Management System (FMS) for some years (Visser, 1991). Its usage is largely confined to business management such as travel time control (Quiroga & Bullock, 1998). In most FMS applications, users can specify an address location and then set a permitter around the area as shown in Figure 5. The GPS coordinates are transmitted at set time intervals from the personal digital assistant (PDA) which is mounted inside the vehicle. If the vehicle is in an area that mobile reception is not available, the coordinates and timestamps are stored inside the PDA, until such time that mobile reception is re-established (Chiang & Huang, 2008).

4.2 Geo-fence

According to a study by the Pennsylvania University RFID Study Group (2006), the major issue in the use of GPS for goods tracking in supply chains is the difficulty of system interoperability. The only key data being transmitted over the mobile network is the GPS data. This usually consists of longitude, latitude, current speed, headings, and altitude

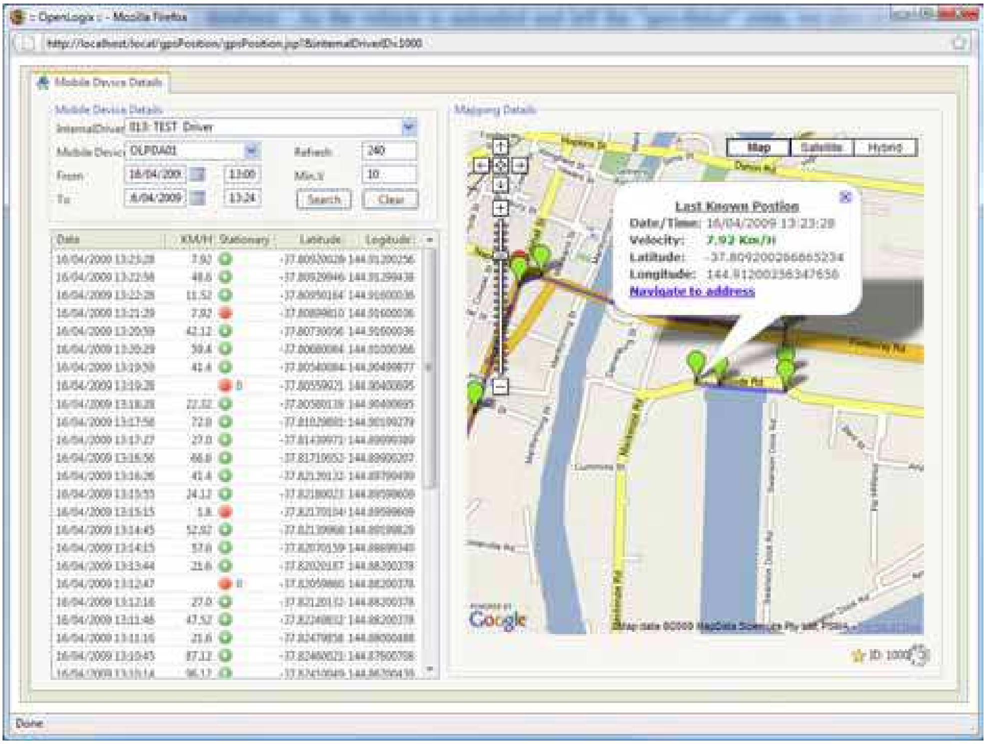

Fig. 5. Vehicle tracking using GPS

(Behzadan et al, 2008). Most GPS solutions would incorporate mapping database which allow users to locate the vehicles' locations. Since the mapping database is proprietary to the GPS software, it is inaccessible to any other applications. This makes it impossible to provide accurate interpretation of the GPS data in the map. Therefore, a system architecture that is flexible enough to adapt to device incompatibility is required for integration with RFID implementation.

A mobile server can be configured as an agent to filter out any invalid signal and feed useful information to the track and trace service. This can trigger a pre-defined process when the event profile is detected. Theoretically, for goods track and trace in logistics, the mobile server keeps track of GPS coordinates against the defined virtual geo-fence. When a vehicle enters the valid geo-fence zone, an arrival timestamp is stored inside the FMS. An event will be triggered that leads to a set of predefined tasks being put to action, such as an update on the job status or on an EPC-IS database. As the vehicle is unloaded and leaves the virtual geo-fence, the departure timestamp can be stored and vehicle loading time calculated.

The geo-fence allows emulated RFID data to be used at locations where installation of the RFID infrastructure is not possible. In Figure 6, a company's enterprise resources planning (ERP) system has been integrated with EPC-IS to provide track and trace functionality for its goods delivery. This tracing capability works well within the company's boundaries. Event management of the local system will update the consignment with all EPCs of goods and the truck that is assigned to this route. Once the truck leaves the depot, the connection of the consignment to the EPC Network is lost. In a virtual geo-fence environment, the task of tracing the truck can then be moved to the FMS module.

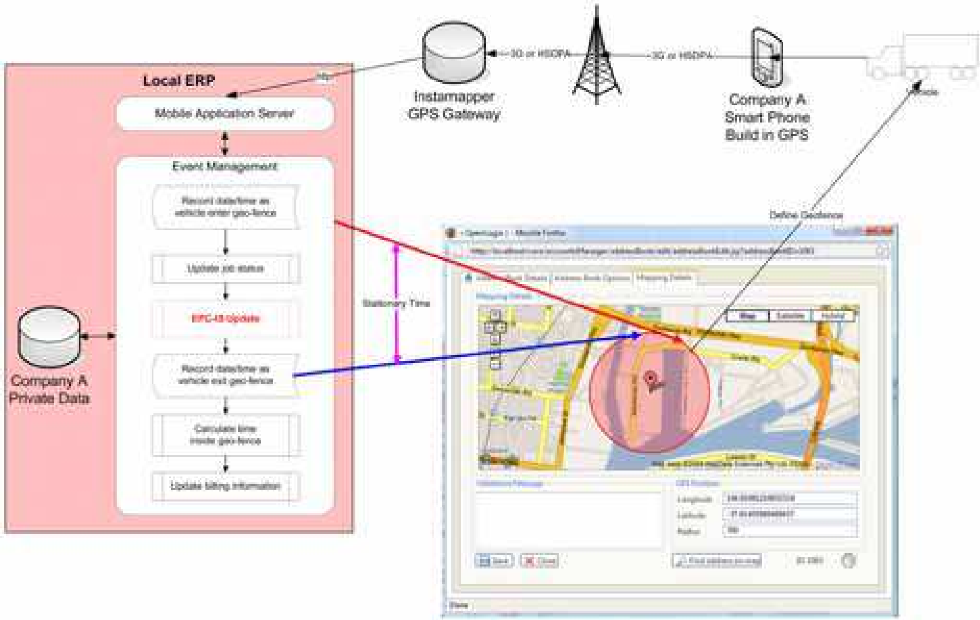

Fig. 6. Geo-fence data integrated with ERP

It is noted that, the actual arrival timestamp will be the time when the system detects the vehicle's entry into the geo-fence. This is dependent on the size of the geo-fence (i.e. the logical radius) and GPS update interval. Such restriction will limit its accuracy when compared to directly reading the tag by RFID readers. It is however very cost effective to have the geo-fence as a virtual gate, since the only capital cost involved would be the GPS which is now a standard tool in most logistics operations.

4.3 QR Code

QR Code or 2D Barcode, was developed by Denso-Wave in 1994 (Walsh, 2009). The term "QR" is derived from "Quick Response". It is essentially a printed "image" containing data (Figure 7), which when photographed by a camera phone, can decode the information encoded in the image. It is developed for high demand, fast moving environment. QR codes has an error correction encoding, and can hold the data intact, even if 30 percent of the printed image is damaged or obscured.

QR Code can store a lot more data in a given area when compared to conventional barcode. Information such as product code, serial number and manufactured date can be encoded using a QR Code. The content of the encoded message can be stored as text format which can then be parsed using a delimiter to extract the field content. It is important to

acknowledge that if data were to be stored in this manner, an agreed field format between the recipient and sender must be established. For this reason, it is a common practice to encode only the URL link, as pointer to a particular web portal, where detailed information can be retrieve externally. Since the information is stored externally, it can be updated in real-time environment.
QR code can be quickly decoded on virtually any computing device that connects to the Internet. Apart from normal desktop and laptop computers, most mobile phone have an in-build camera which can read the QR Code, decode it with a free software inside the phone and then either link them to a website, or store the entire business information somewhere in a server. Typical mobile phones such as Apple iPhone and most Nokia phones have been proved to work seamlessly with this code.

Fig. 7. QR Code encoded URL: http://www.rmit.edu.au

Since all SMEs will have this type of infrastructures (e.g. mobile phone with camera) the cost to implement within the business consortium is just the normal cost of printing, but the opportunity gained is substantial. The biggest potential benefit to the SMEs is the ability to link virtually everybody (carrying a mobile phone with access to the Internet) with digital data that can be immediately acted upon. This will eliminate any misunderstanding in verbal communications, legal and contractual fulfilment, errors in picture scanning, multimedia data, network breakdown and other issues related to reliability of business information. QR codes can be generated, re-generated, enhanced, added to, encrypted as necessary making it the most flexible and mobile data structure that can be used in business. The new data structure will also enable more variety of business models, especially in marketing, business networking and other day to day communication activities.
QR code area size is largely depended on the size of the encoded data. The accuracy of the QR Code is heavily depended on the quality of the input image. Thus, the bigger the data, the better the image need to be captures.
In the case that RFID infrastructure are not available, the shipment goods information can then be scanned manually with a digital camera from a mobile phone. QR code decoder could also be integrated as part of the security camera to decode the freight as it is being unloaded from the loading bay.

5. Transparent framework

Making use of the geo-fence and QR code technologies, the virtualised infrastructure requires integration of several key functions. Ubiquitous computing has been investigating since 1993 (Weiser, 1993). The major character of ubiquitous computing is to create a user centric and application orientated computing environment (Wang et al, 2008). The theory of ubiquitous computing is to integrate information from a large number of sources. By being everywhere and any time, huge amount of data can be collected and process via ubiquitous supply chain. Complex algorithm and computation can be utilised in real time, and only the relevant key information is then feed back to the physical systems and the stakeholders within their supply chain domain. However, the theory of ubiquitous computing is difficult to extend to real physical world unless there is a schema with defined scope.

We developed the system "Transparent" based on ubiquitous theory to manage the global logistics processes, with the application of RFID, mobile devices and virtualization technology. Figure 8 demonstrates the flow of information between various terminals, shipping lines and Australian Customs. Using the Transparent Gateway, all the public (vessel and voyage details) and private data (container status) for each carrier are synchronized. The data feedback from the private Transparent Gateway can also trigger an event which can update container status inside the each company's enterprise resources planning (ERP) system.

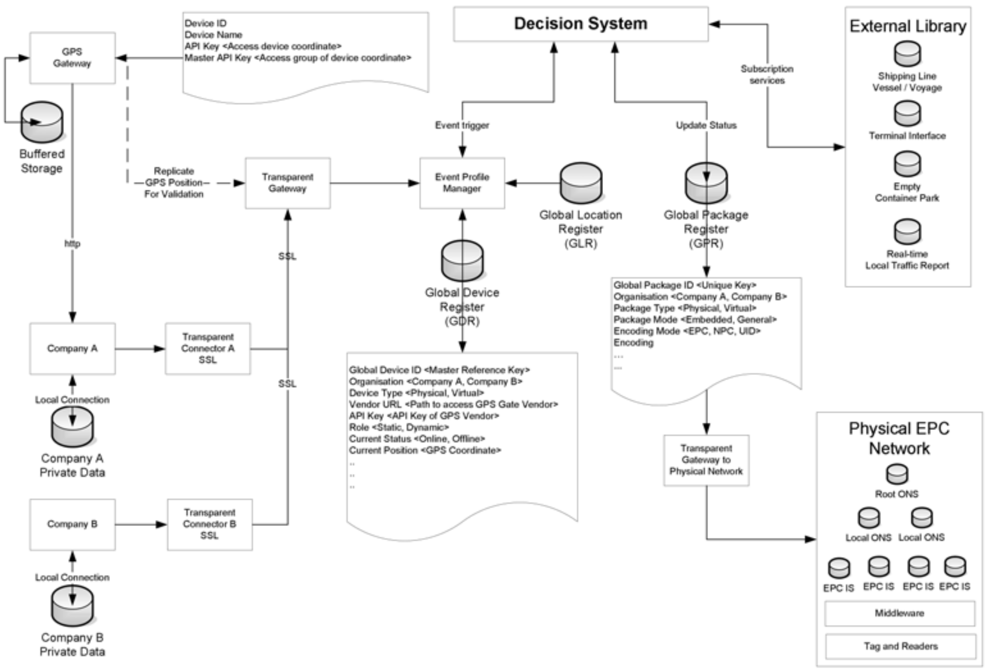

Fig. 8. Overall Design of the transparent virtual framework

The focus in Figure 8 is to keep track of each Stock Keeping Unit (SKU), and not on where it is coming from or going to. A clear record on the location of a SKU and trade unit number (TUN) in the supply chain must be kept. When an advance shipping notice (ASN) is received, the warehouse needs to accurately account for each item inside the package, and put them away at a set location inside the warehouse.

5.1 Distribution service

The supply chain process is reversed when an order is issued to the warehouse to deliver goods to another party. The SKU from a defined location is packed onto a pallet with a Serial Shipping Container Code (SSCC) attached. An ASN is then sent out to the recipients with a list of SSCCs and the items within. At this stage, a freight label is created and then applied to the SSCC. The freight label does not have any correlation to the SSCC but simply tells the truck driver how many packages he is picking up per consignment. It is within this transition that the link is broken, and in most cases two separate systems are used to capture this information. When the freight arrives at the recipient, only package details are captured, not the SSCC. The recipient will then need to re-identify the SSCC by visually checking or scanning the actual package.

The problem becomes more complex when barcodes are replaced by RFID tags. Since the warehouse and the transport company may not be the same entity, two different RFID systems may be used for the same purpose. This adds to the cost and defeats the integrity of the identity. There are security concerns that the package will need to be kept intact between dock locations. This issue has been investigated in some of the RFID pilot studies. A proven approach is to enhance the normal verification process known as "pick face" to ensure identification of items to the SSCC. A typical "pick face" process can be described in the following steps (Figure 9):

1. Bring up the interface in the browser and enter the purchase order number. When the order number is accepted, the system expects to scan a pallet.
2. The operator uses a mobile reader to scan the pallet tag. The system would check the EPC and only accept a GRAI tag. The operator then selects the product that would be packed.
3. The operator applies the tags to the cartons and uses the mobile reader to scan the tags until the required number is reached.
4. Products scanned are displayed on the screen.
5. The operator scans and applies a shipment tag to the package.
6. The system asks for the next pallet. The operator could either continue for another pallet or close the pick process. In the latter case, the system would return to Step 1.

All EPC information is captured immediately to the local server and subsequently uploaded to the global EPC-IS. Containment information is associated with the pallet which is registered prior to this pick face process.

Once the items are validated as one containment, the package is wrapped and sealed to prevent further altercations.

Using Transparent Gateway, the SSCC and the order fulfilment can be easily updated by querying the Transparent Framework. Since the SSCC as well as the physical RFID tags number are embedded inside the Transparent virtualized tags, the same set of information can be filtered across to the physical network, including the status and event of the physical system that can also be transposed to the virtual system.

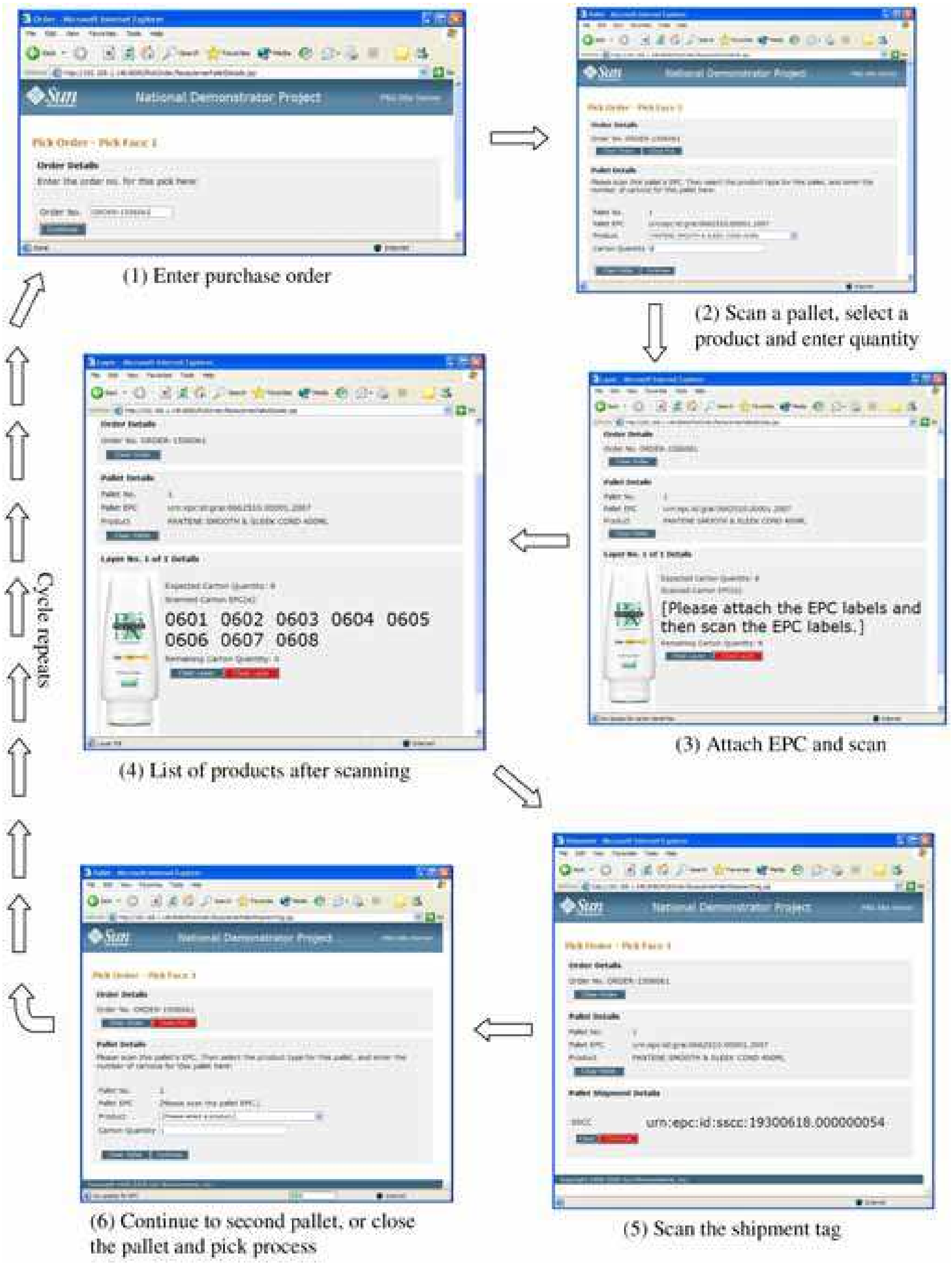

Fig. 9. Pick face process and screens

5.2 Data validation

Using Instamapper (http:/ / www.instamapper.com) API (Application Program Interface), GPS data are synchronised to the local company's FMS or ERP database to trigger an event when a vehicle travel within the geo-fence at a defined moment in time. Since this GPS data are critical in terms of creating an event, such as changing ownership, etc, it is not desirable to depend on one source of data. Data that are stored locally can be tampered, which could then lead to data integrity and creditability issue. One solution is to allow the same set of data to also pass to the Transparent Gateway. When an event is triggered from a local database, it is verified by the data that are collected directly from the buffered storage within Instamapper. Since the data from Instamapper (or any other GPS Gateway companies) are independent and cannot be tampered with, if both set of data are identical, the event triggers are valid, otherwise, the relevant parties are notified and security investigations will be initiated.

5.3 Global registers

There are three primary registers that exist within the Transparent Framework. These registers are used to maintain instances of physical objects that would exist in various ERP, FMS and web application. Transparent then use this registers as access keys to connect to various systems.

5.3.1 Global Device Register (GDR)

When a local device is registered with Instamapper, a device ID is created within the GPS Gate local network. In a real-world environment, there could be multiple GPS gate providers. Therefore, the device ID cannot be assumed unique. Encapsulation of all device IDs in a Global Device Register (GDR) class is to manage ID information in order to ensure uniqueness in the system. Since the GDR can be referenced to a company, the GPS device can be assigned dynamically to trucks and other ID devices. Each GDR can have a defined event profile build in and managed by an Event Profile Manager. An event profile is a set of rules and parameters that controls the behaviour on how each GDR should behave when interacting with a Global Location Register (GLR) or another GDR at a specified condition.

5.3.2 Global Package Register (GPR)

The same principle applies to the Global Package Register (GPR). Since EPC network is not the only network in the global supply chain, the system will need to encapsulate each tags in a GPR class. For example, RFID information can flow to and from different networks, such as NPC, UID as well as within the virtual network. Data travel between physical networks is also managed by Transparent Gateway.
QR code may be a good medium to encode "Global Package Register Identification Number" (GPRID) from the proposed "Transparent" framework.

5.3.3 Global Location Register (GLR)

Unlike GDR and GPR, the global location register (GLR) operate almost in the reverse. Since a particular location, such as an office building or a consolidate warehouse could house multiple organisation unit. Therefore GLR is used to identify a location that resides within the domain of a particular organisation.

5.4 Decision system

The aim of the virtual network is to allow non-conforming systems to interact with conforming systems such as those of EPCglobal. However, the primary goals should not only be limited to traceability and visibility, but management of information so that decision paths could be established. Information gathered across the framework could then be synchronised with shipping line, terminal operators, customs agencies, empty container parks or even local traffic to further optimise the performance and the transparency of each process within the entire supply chain.

6. Traceability in a virtual infrastructure.

In order for both physical and virtual systems to be coordinated with each other, a communication path is required between a physical to virtual system (P2V) and vice versa. The physical scanners are not only given a unique location code within the EPC network, they are also given a global device register (GDR) number which is a unique attribute across the Transparent framework. Since there could be a single physical RFID scanner that acts as a host for multiple network such as NPC and UID, by obtaining a unique GDR, we can keep track of the physical device, regardless of which network it is operating in.

Figure 10 illustrates how a physical EPC infrastructure interacts with a virtual infrastructure environment in a typical distribution environment. A container is unpacked and the product encoded with EPC tags are then scanned (via GDR:P00001, which is type ‘static’) and stored as inventory. An order is then created and the product is issued out via a typical scan pack system. SSCC labels are generated and displayed as barcode to the outside packaging. At the same time, a global package register identification number (GPRID) is also created, which acts as a key between different networks, physical and virtual. The GPRID is then scanned to create a manifest of the vehicle, which is managed by an internal FMS. The GPS unit inside the truck contains a GDR number (GDR:V00001), which is type ‘dynamic’. Within the FMS, the geo-fence of the destination has a global location register number (GLR:L00012). The virtual EPC network constantly checks for any device of type ‘dynamic’ that falls inside the geo-fence. Thus, if GDR:V00001 is inside location GLR:L00012, within the specified delivery time window in the FMS, a scan event from the emulated scanner GDR:P00003 is raised and the location of the GPRID is then updated in global package register (GPR) database. The GPR acts as an intermediate storage between the physical and virtual environments, since GDR:P00003 may not exist as a registered device in the physical EPC network.

The final order is issued from GLR:L00012 to a delivery location GLR:L00014. A new GPRID is created for the order based upon the original GPRID, once the SSCC is scanned from GDR:P00005 (physical, static device). The scan event is then raised within the physical EPC network and the GPR is updated.

It is important to note that we will only update the physical EPC network when a physical reader is utilised. We cannot update the physical EPC network directly from the virtual system, because the virtual reader may not exist as a register device in the physical EPC network. Thus, the only way to accurately query the physical and virtual data is via the global package register (GPR).

Since both physical and virtual environments can coexist in the supply chain, GPS data from GDR:V00001 can be used to forecast the delivery time accurately. This is particularly useful for those who operate a just-in-time (JIT) operation, where supply punctuality is critical. A virtual enterprise system not only improves the visibility of the supply chain, but also increases the performance of the overall supply chain with the utilisation of the real-time data to drive business decision in a time sensitive operation.

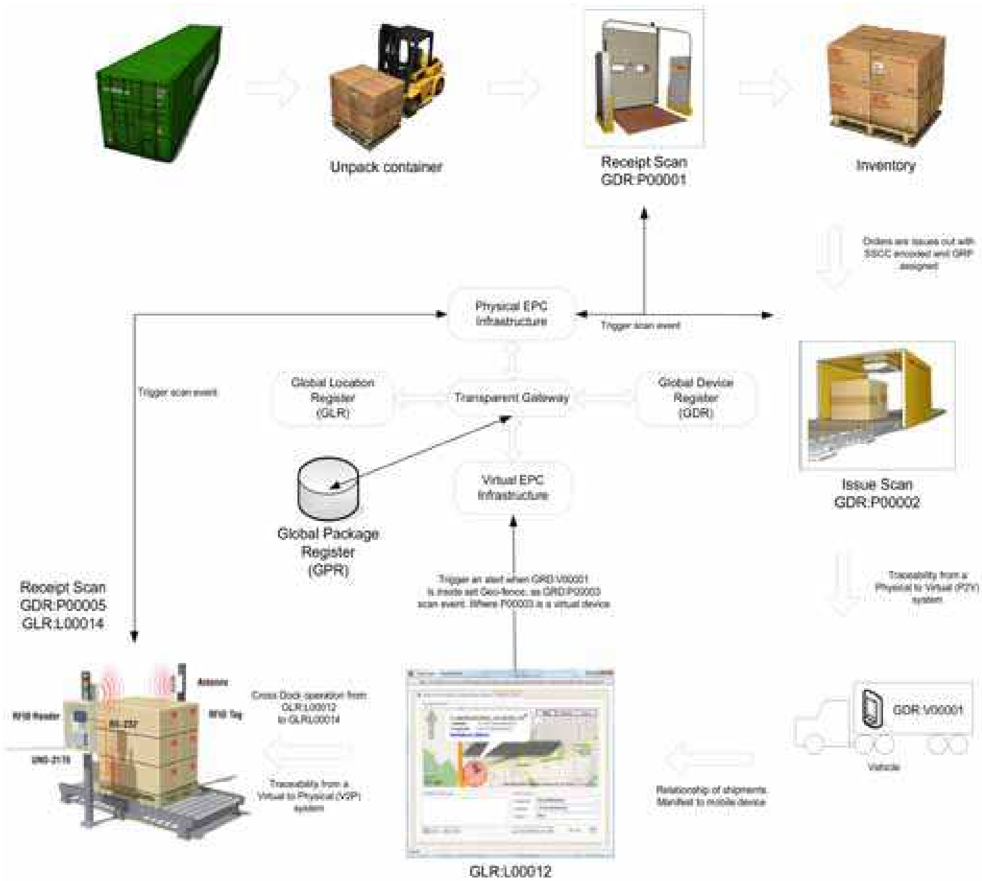

Fig. 10. Traceability of items in the virtualised supply chain

7. Conclusion

In this chapter, we have discussed the use of RFID system in two Australian national demonstrator projects (NDP and NDP Extension). The ability to scan without line of sight proved is the key advantage of RFID over conventional barcode scanning. However, the capital investment and maintenance cost is too much for some SME organisations.

To overcome these issues, this chapter demonstrates how GPS can be used to develop a geo-fence system that tracks consignments at locations where RFID systems are in accessible. This chapter further illustrates QR code, which supports multiple scanning via image recognitions. QR code can store much more information when compared to conventional barcode. With the utilisation of a modern mobile phone with a build in camera, QR code can be scanned, showing text, SMS, contact details or a link to a website. This enable QR code to act as a pointer to extract information stored externally. These information can be updated and manage in real-time, similar to those of RFID.

These technologies are then integrated with the model Transparent, which is based on ubiquitous computing. Transparent act was a router between physical and virtual infrastructure. It facilitates backend ERP and FMS systems using GPS technology and geo-fence to emulate event that are feed back to the physical RFID network. This ensures that data are captured along the supply chains, even if the receiving or sending parties may not be RFID ready. Transparent can also support multiple physical RFID system such as NPC, and UID.

In a supply chain that operates at high volume and low profit margin, very few businesses are willing to invest into new and evolving technologies such as those of RFID. Most of these businesses are SMEs that do not have the capital resource to purchase and maintain such technologies. Transparent offers a low cost virtualisation solution to such supply chains, by providing a communication path to those larger companies that have already invested heavily in such technologies.

8. References

Behzadan, A.H., Aziz, Z., Anumba, C.J, Kamat, V.R. (2008). Ubiquitous location tracking for context-specific information delivery on construction sites. *Automation in Construction*. August, 17(6):737-738

Chauhan, S.S., Proth, J.M. (2005). Analysis of a supply chain partnership with revenue sharing. *International Journal of Production Economics*. 97(2):44-51

Chiang, K.W. and Huang Y.W. (2008). An intelligent navigator for seamless INS/ GPS integrated land vehicle navigation applications. *Applied Soft Computing*. 8(1):722-733

Demchenko, Y. (2004). Virtual organisations in computer grids and identity management. *Information Security Technical Report*. 9(1):59-76

EPCglobal Inc. (2006). EPCglobal Tag Data Standards, Version 1.3.1, March 8, 99 pages

Gajzer, S. (2007). Process Modelling and Development of the Key Performance Indicators for the National Electronic Product Code Network Demonstrator. *MEng Dissertation*. RMIT University

Hamilton, J.W. (1993). Wireless communication systems: a satellite-based communications approach for competitive advantage in logistic and transportation support services. *Computer in Industry*. 21(3):273-278.

Kelepouris, T., Pramatari, K., Doukidis, G. (2007). RFID-enabled traceability in the food supply chain. *Industrial Management and Data Systems*. 107(2):183-200

Kim, G. (2008). Seven steps to a secure virtual environment. *Network Security*. 2008(8):14-18

Liu, C.H., Sia, C.L., Wei, K.K. (2008). Adopting organizational virtualization in B2B firms: An empirical study in Singapore. *Information and Management*, Nov., 45(7):429–437

Mo, J.P.T. (2008a). Development of a National EPC Network for the tracking of fast moving consumer goods. *International Journal of Enterprise Network Management*, 2(1):25-46

Mo, J.P.T. (2008b). Modelling and Simulation of National Electronic Product Code Network Demonstrator Project. *International Conference on Information Systems (ICIS 2008)*. 14-17 December, Paris, France

Mo, J.P.T., Gajzer, S., Fane, M., Wind, G., Snioch, T., Larnach, K., Seitam, D., Saito, H., Brown, S., Wilson, F., Lerias, G. (2009a). Process integration for paperless delivery using EPC compliance technology. *Journal of Manufacturing Technology Management*, 20(6):866-886

Mo, J.P.T., Sheng, Q.Z., Li, X., Zeadally, S. (2009b). RFID Infrastructure Design: A Case Study of Two Australian National RFID Projects. *IEEE Internet Computing*. 13(1):14-21.

Pedro, M., Reyes, P.J (2007). Is RFID right for your organization or application? *Management Research News*. 30(8):570-580

Pennsylvania University RFID Study Group (2006). Challenges in RFID enabled supply chain management. *Emerald Management Reviews*, ISSN:0033-524X, Nov, 22-28

Quiroga, C.A., Bullock, D. (1998). Travel time studies with global positioning and geographic information systems: an integrated methodology. *Transportation Research Part C: Emerging Technologies*. 6(1-2):101-127

Soppera, A., Farr, J, Kasten, O., Illic, A., Zanetti, Z., Harrison, M. (2007). Supply Chain Integrity (D4.6.1), Building Radio frequency IDentification for the Global Environment (BRIDGE Project Report), Dec, WP04, European Commission contract No: IST-2005-033546, 22 pg.

Visser, H. G. (1991). Terminal area traffic management. *Progress in Aerospace Sciences*. 28(4):323-368

Walsh, A. (2009). Quick response codes and libraries. *Library Hi Tech News*. 26(5-6):7-9

Wang, H., Zhang, Y., Cao, J (2008). Access control management for ubiquitous computing. *Future Generation Computer Systems,* 24(8):870-878.

Weiser, M. (1993). Hot topics-ubiquitous computing. *IEEE Computer*. 26(10):71-72.

Zarour N., Boufaida M., Seinturier L., Estraillier P. (2005). Supporting virtual enterprise systems using agent coordination. *Knowledge and Information Systems,* September, 8(3):330–349, Zito, R., D'Este, G., Taylor, M.A.P. (1995). Global positioning systems in the time domain: How useful a tool for intelligent vehicle-highway systems? *Transportation Research Part C*, 3(4):193–209

Sustainable Radio Frequency Identification Solutions
Edited by Cristina Turcu

ISBN 978-953-7619-74-9
Hard cover, 356 pages
Publisher InTech
Published online 01, February, 2010
Published in print edition February, 2010

Radio frequency identification (RFID) is a fascinating, fast developing and multidisciplinary domain with emerging technologies and applications. It is characterized by a variety of research topics, analytical methods, models, protocols, design principles and processing software. With a relatively large range of applications, RFID enjoys extensive investor confidence and is poised for growth. A number of RFID applications proposed or already used in technical and scientific fields are described in this book. Sustainable Radio Frequency Identification Solutions comprises 19 chapters written by RFID experts from all over the world. In investigating RFID solutions experts reveal some of the real-life issues and challenges in implementing RFID.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821