Development of End-to-End Global Logistics Integration Framework with Virtualisation and Cloud Computing

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Degree of Doctor of Philosophy

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Declaration

I, Weerayut Lorchirachoonkul, hereby declare that the PhD thesis entitled "Development of end-to-end global logistics integration framework with virtualisation and cloud computing":

a) Except where due acknowledgement has been made the work is that of the candidate alone;

b) The work has not been submitted previously, in whole or in part to qualify for any other academic award;

c) The content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program;

d) Any editorial work, paid or unpaid, carried out by a third party is acknowledged;

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Acknowledgement

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Thesis Abstract

End to end global supply chain network information integration and collaboration cannot be solely dependent on a single technology or platform. There are many technologies that exist and are being utilised currently in different industry sectors within the global supply chain network. These technologies are rigid and not adaptable to new standards and workflow, thus, causing compatibility, adaptability and interoperability issues to the global supply chain information network. As a consequence, under resourced organisations who do not have the capacity to invest in up-to-date technologies to conform with current global supply chain standards, often cause delays in communicating supply chain information, which cost millions of dollars to fix, resulting in the distortion of inventory demand known as the “bullwhip” effect.

This thesis, discuss the design and development of virtualisation technologies that enable the capacity to develop Global Logistics Integration Framework (GLIF) that incorporates the integration of fixed, mobile and virtual devices with different supply chain systems so that they can be integrated seamlessly together. The GLIF enables mapping of sensors, location, item and packages known as Global Registers (GRs) in supply chain logistics. As data flows from each GR, it is monitored using different Event Binding Managers (EBMs) that interpret the interaction of each GR instance, then transfer the virtual events back into the physical network.

The adaptability and the interoperability of GLIF enables development of a new automated check-out model that utilise an array of 3D point cloud cameras to detect users’ gestures and integrated with matching array of high-resolution 2D cameras to further assist with the object detection and validation. Unlike conventional mobile check-out interface, the proposed system does not require the user to interact with any handheld devices.

The development of an end-to-end global logistics integration framework enables the data obtained from different data-capture devices, from different supply chain systems to be collaborated into a single framework. With the aid of virtualisation concept and cloud computing technology, the embedded services in GLIF can be modelled as cloud services so that it can be hosted independently, hence providing flexibility and scalability to the framework.
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<td>3G</td>
<td>Third Generation mobile telecommunication technology</td>
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<td>3PL</td>
<td>Third Party Logistics</td>
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<td>4G</td>
<td>Fourth Generation mobile telecommunication technologies</td>
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<td>APP</td>
<td>Mobile Application</td>
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<td>A-GPS</td>
<td>Assisted Global Positioning System</td>
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<td>API</td>
<td>Application Program Interface</td>
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<td>AQIS</td>
<td>Australian Quarantine and Inspection Services</td>
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<td>CaaS</td>
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<td>CNAME</td>
<td>Canonical Name record</td>
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<td>CPFR</td>
<td>Collaborative Forecasting Planning and Replenishment</td>
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<td>Customer Relationship Manager</td>
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<td>General Packet Radio Services</td>
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<td>Global System for Mobile Communication</td>
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<td>Integrated Circuit</td>
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<td>Vehicle Booking Systems</td>
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<td>Virtual Machine</td>
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<td>Vendor Managed Inventory</td>
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<td>Voice over Internet Protocol</td>
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<td>XML</td>
<td>Extensible Mark-up Language</td>
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Chapter 1 Introduction

1.1 Background of Research

A “manufacturing based supply chain” contains a broad spectrum of partners, including manufacturers, freight forwarders, shipping line, third party logistics providers, distributors and retailers. All of them has mixed modes of value adding processes. An important success factor for this type of supply chain is the ability for the partners to identify and track products moving through the supply chain, using the latest information technologies (IT) (Barratt, 2004). However, these value enhancements would vary substantially according to the nature of the partners’ business requirements. As such, the flexibility of managing the IT infrastructure for supporting value adding activities is the utmost importance.

Figure 1.1 Workflow of global supply chain
In a global supply chain, products are shipped from manufacturer and consolidated into a freight station (Figure 1.1). The freight forwarder acts as an outbound collaborator between the manufacturer, freight station, wharfs cartage, export terminal and the shipping line (Yen et al., 2003). The outbound wharf cartage company is responsible for coordinating the empty container from the empty container park; delivering it to the freight station, re-collecting the container to a holding yard and sending it to the export terminal, where the containers are loaded to an export vessel.

Once the shipping line has confirmed the export container is on the vessel, the freight forwarder would send the required documentation, such as a commercial invoice to the inbound custom broker, in which appropriate import taxes and duties are applied to the client. Only when all the taxes and duties are paid, the local customs will then allow the shipping line, and terminal to release the inbound container to the local wharf cartage company. The local wharf cartage company is then responsible for delivering the container to the distribution centre, where it can be inventoried and re-distributed into retail outlet. Once the container has been unpacked, it is the responsibility for the inbound wharf cartage company to collect the empty container from the distribution centre and deliver it to an empty container park so that it can be reused again for export.

It is common for a container to be put “on hold” by local customs or quarantine and inspection officer. For example, if the taxes and duty were not paid on time, the local customs would instruct the terminal and the shipping line to put the container on hold, in which additional administration and terminal storage charges would apply to the client. Likewise, in the event that inbound containers contain elements of dirt, the entire container will have to be redirected to a steam clean depot to avoid Foot and Mouth Disease (FMD) (Peck, 2005).

The inbound container can also be randomly re-directed to the X-Ray or visual inspection (Tailgate inspection) depot (Sarathy, 2006). Real-time information sharing is therefore, critical to all dependent parties including: inbound terminals, wharf cartage, freight forwarder, quarantine and inspection depots, distribution centres and client, since scheduled labour and resources will need to be redirected and/or reallocated to another container. It is
important to note that within the global supply chain, the connectivity between each party is segmented. All terminal operators in Australia operate on their own legacy systems which are isolated to all outside parties. Therefore, the user have to manually enter a web-portal with a valid username and password and navigated through various menus in order to retrieve a status of a container. In the event where the container is marked as "on hold", no notification is sent to the key stakeholder. Therefore, it is up to each party to monitor container status from each terminal legacy system. This is time consuming and prone to human errors.

Electronic Data Interchange (EDI) is used to facilitate communication and information exchange between supplier and customer (Tan et al., 2010) and is widely utilised in Australian supermarket and retail supply chains. However, EDI is an expensive process to establish that requires hardware, software and data capture devices to be purchased. There is also high recurring and transactional costs involve in managing Value Added Network (VAN) that provides connectivity between trading partners (Waller et al., 1999). Recent internet cloud technologies can be leveraged as an alternative to VAN. However, there are always risks and security concerns when transactions are conducted over the internet cloud (Sila, 2013).

There are many types of operating systems and database platforms used to develop applications in global supply chains today. Within each application, there are various protocols and drivers that are used to interface between the application and its platforms. However, many application vendors are not willing to allow access to their databases, fearing that they would be exposing their Intellectual Property (IP) to their competitors (Naumovich et al., 2003). Thus, interface between applications can only be executed via costly customs interface provided by application vendors. Gunasekaran et al. (2004) suggested that poor integration and compatibility between different IT systems for major stakeholders in global supply chain systems are the result from lack of strategic planning and poor IT infrastructure. Since data synchronisation between data legacy capture devices and applications are closely coupled, the decision to choose the data capture device is totally dependent on software compatibility and not the device's ability to capture data.
RFID technologies are increasingly used in supply chain management (SCM), due to the ability to read multiple tags simultaneously without line-of-sight (Tajima, 2007). Passive RFID are inexpensive (Weinstein, 2005) and can be utilised in supply chain operations from the supplier to the distribution centre, warehouse and point of sale. Although adoption of homogeneous logistics IT systems such as EDI and RFID may benefit from short term competitive advantage, the supply chain is not sustainable in the long term unless they are also coupled with heterogeneous capable frameworks (Hazen et al., 2011). Furthermore, RFID suffers from technological constrain that directly influence the readability of the RFID tags, resulting in unexpected read event are refer to as ‘false-negative’ (Metzger, et al., 2013). While ‘tag-collision’ (where RFID tags transmits data to a RFID reader at the same time, preventing tags from being read) can be almost eliminated using complex anticollision protocols such as ‘EPC Gen 2’ (Bueno-Delgado, et al., 2013). However, ‘tag-detuning’ (where a shift in resonance frequency cause by other tags, liquid or metal in surrounding area) resulting in reduced scan rate and mis-scanned (Singh, et al., 2009). Unlike tag-collision, tag-detuning phenomenon is a direct constrain with Radio Frequency (RF) communication technologies, while the effect of tag-detuning can be reduced with the enchancement of Integrated Circuit (IC) and antenna design, the fundamental technological constraints of RF still remains.

Therefore, like most emerging technologies, there are different vendors, standards, systems, applications, appliances and processes that co-exist. 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, under resourced supply chain firms simply do not have the capacity to invest in emerging technologies such as RFID, thus, resulting in the distortion of inventory demand known as the “bullwhip” effect (Machuca et al., 2004).

Studies conducted in supply chain technologies, such as RFID are largely based on an assumption of a three tiers network (Gaukler et al., 2007), from manufacturers to distribution centres and retail outlets (Butcher et al., 2012). However, in a global supply chain the workflows are much more complex than those of a three-tier network (Peck, 2005). As new sensor technologies such as RFID are introduced to the supply chain network, there are costs involve in implementing and maintaining such technologies. In many cases, technologies can be outdated and obsolete before they are fully rolled out. Therefore, most supply chain
partners, including retailers, are unwilling to embrace new technology and that prohibits further improvements in the supply chain. To enable collaboration, new technologies are required to be cautiously introduced into the supply chain management systems. Moreover, the middleware and firmware must be easily updated to improve the performance and compatibility of the devices to existing and future supply chain integration models. These direct the related research to develop new end-to-end global supply chain integration systems.

1.2 Objectives

This research aims to develop an end-to-end global logistics integration framework that enables cross supply chain collaboration and is not restricted to state of technologies. The research looks at the key logistics information technologies and develops a framework that overcomes the current constraints to integration. The framework then forms the foundation platform to adapt technologies and workflow that are open, flexible and scalable.

Therefore, the research has the following objectives:

1. Investigate the characteristic of current data capture technologies and develop an emulation model for both fixed and mobile devices which are best to be used in conjunction with the virtual appliance model.

2. Develop new interface methodology and processes that will interact with legacy systems with the latest virtualisation concept and cloud computing technology.

3. Create new methods of end-to-end integration of global logistics framework that enables new technologies and standards to be implemented with the proposed new framework.

4. Demonstrate the reusability of elements of the logistics integration framework so that it can be used as a platform to develop future applications.

The outcomes of this research form the basis for collaboration of different industry sectors in the global supply chain particularly using mobility services that can be used in the new virtual infrastructure.
1.3 Research Plan

The research plan is divided into three major components. The first component consists of the literature review and evaluation of the existing work supply chain workflow. The literature reviews surveys current supply chain workflow and identifies system gaps that exist between key stakeholders within the global supply chain. As part of the supply chain technologies review, identification technology such as traditional barcode and radio frequency identification (RFID) are analysed, as well as emerging identification technology such as 2D Barcode, near field communication (NFC) and smart shelf. Virtualisation concept and cloud computing technology are identified as key components in the establishment of the global logistics integration framework.

The second component consists of four experiments:

- Development of the Virtual Mobile Appliance (VMA) model

  The virtualisation concept is used to develop the VMA model, where smartphone sensors are used as virtual appliance hosts.

- Implementation of VMA using geo-fences

  The VMA model is then implemented with GPS sensors from the smartphone to emulate RFID events.

- Utilisation of Internet Screen Agents (ISA) to interface legacy systems

  ISA and cloud computing platform are also used to perform tasks that would normally be conducted by humans to interface to legacy systems.

- Development of a lightweight communication interface for low-bandwidth implementation of VMA.

  For time critical tasks, ISA can balance the load between network clusters. The sub-cloud clustering approach was developed in conjunction with the Queued Burst Data Compression (QDBC) Model to provide connectivity to cloud services in low-bandwidth connection environments.
The third component packages the interfaces from the second component into API that can be re-used by other application developer. As examples, these components are implemented in a global logistics integration framework implementation code name “Transparent”. Two experiments were conducted as part of Transparent Framework evaluations including a local milk distributor and a wharf cartage company in Melbourne, Australia. In order to demonstrate the adaptability and scalability of “Transparent” Framework, a new scan-less checkout technology was incorporated. The Ubiquitous Gesture Interpreter (UGI) model utilised arrays of high resolution CCTV cameras and 3D point cloud cameras to manage and monitor the state of shoppers for an automatic scan-less checkout model.
1.4 Structure of Thesis

The thesis is divided into four main sections. Chapter 1 and 2 introduce the research concept and discuss the current contributions made by various researchers to date. All related citations are grouped into sections so that they can be correlated within each research chapters.

Chapters 3, 4 and 5 are the explanation of the different virtualisation and emulation model used in the global logistics integration framework. In particular, the development of virtualisation and cloud computing models for mobile virtual appliance used in scan pack logistics, and utilising Internet Screen Agent (ISA) to map data from integrated systems to legacy systems. The concept of mobile virtual appliances which GPS receivers in smartphones are used as input parameters as part of geo-fence event interpreters for virtual infrastructure framework are discussed in Chapter 4. Chapter 5 evaluates the proposed data compression model low-bandwidth end points which are common in mobile data connections.

Chapters 6 and 7 summarise the research work in previous chapters and integrate each component into the global logistics integration framework. These enabled virtual emulation such as VMD to communicate directly with physical devices via managing instances using global registers. The reusability of global logistics integration framework with Microsoft Kinect 3D cameras to create ubiquitous retail checkout systems will be demonstrated in Chapter 7.

Finally, chapters 8 and 9 evaluate the merits and negatives of the global logistics integration framework components and as an overall effectiveness of the framework. The conclusions based from the research findings of this thesis give an insight on future research opportunities. The author’s publications to date are shown in Appendix 1.
1.5 Research Methodology

The development of global logistics integration framework is based on Rapid Application Development (RAD) methodology that promotes strong collaborative atmosphere and dynamic gathering of global supply chain requirements. Unlike Waterfall and Spiral Models that are sequence driven, RAD also enables key stakeholders to participate in prototyping and performance unit testing from the development of miniature software projects that are released in small increments so that it can be analysed in a real-world supply chain environment. A user-centric approach that follows an iterative pattern of research, requirement, implementation, review and package into API is applied to each module (Figure 1.2).

The research of current technologies is conducted with extensive literature review and the authors' industry experience as IT managers for many large national and multinational logistics firms. Most of these logistics companies use extensive internet based technologies to communicate within their operations as well as with external trading partners. This research activity provides the basis for determining the functions required by the global supply chain to meet current and future demand in network communication and collaboration among the stakeholders.

Once the functional specifications for global logistics integration framework are established, the design specification can then be created so that the framework core structure can then be prototyped and tested with various emulation modules. The prototype emulation modules can be inserted into existing logistics systems managed by the author and tested with key stakeholders. Upon successful of the emulation tests, the modules are then packaged into reusable application program interface (API). At the same time, scalable and cost effective management model, such as virtualisation and cloud computing can be used as part of the implementation process for global logistics integration framework. To demonstrate the global logistics integration framework’s agility and dynamism, a new ubiquitous data capturing technology is developed using API developed from global logistics integration framework. This new single collaboration framework will be implemented in a number of companies through connections of the author.
To close the loop, a feedback channel has been designed to collect user experience and operating data of the single collaboration framework. However, this process takes time and extends beyond the time constraint of this research study. The feedback is therefore represented by a dotted line as shown in Figure 1.2.

![Figure 1.2 Research Approach](image-url)
Chapter 2 Literature Review

2.1 Introduction

Global supply chain networks cannot solely depend on a single technology or platform. The engagement of all key stakeholders to participate with different technologies and platforms is essential to make the supply chain a success. A collaboration scheme is needed to mesh and translate different technologies and platforms together, in a scalable and agile environment.

The literature review groups functional technologies in the supply chain into sections that specific issues associated with the characteristics of collaborations are evaluated. The challenges of implementing new technologies in these groups to existing platforms are analysed and exploited. Furthermore, this chapter discusses the opportunities for leveraging new IT infrastructure technologies including virtualisation systems and cloud computing technologies to the global supply chain landscape.

2.2 Global Positioning System (GPS)

Global Positioning System (GPS) is a satellite-based navigation system that has been utilised heavily in the logistics industries since the late 1990’s (Jacobs et al., 1991). GPS system are often utilised as part of a Fleet Management System (FMS) that tracked, identified and located vehicles fitted with a GPS receiver (Mintsis et al., 2004). However, the information obtained from the FMS are often isolated from the rest of the logistics system such as Transport Management System (TMS) and Warehouse Management System (WMS) which play a critical role in the Supply Chain Management (SCM) realm (Drane et al., 1998).
TMS were used to capture client, consignee, consignment and billing details (Mason et al., 2007). The shipment, distance, dimension and weight are often used to determine the charges, whereas the costs are often derived from hourly rates generated by company drivers, subcontractors and additional equipment required to fulfil the delivery. Dorer et al. (2005) confirmed that conventional TMS does not have the ability to cope with real-world complexity and on-demand parameter changes such as traffic jams, breakdowns or accidents. Thus, this further highlights the requirement to integrate TMS with other supply chain systems such as FMS and WMS.

Hong-Ying (2009) discussed the impact of barcode technology with WMS in a logistics warehouse operation from data entry error between systems. However due to many types of encoding standard, barcode implementation may not be feasible, especially for global supply chain where different encoding standard exist for the same item code.

Michaelides et al. (2010) presented a case study that focuses on the development of an integrated GPS solution by incorporating Personal Digital Assistance (PDA) to capture the consignment pickup and delivery details including signature (refer to as sign-on-glass) of the recipient as part of the Prove of Delivery (POD) process to further improve control and visibility over inland transport operations.

According to Leung et al. (2012), the motivation for real time visibility by integrating TMS with GPS, GIS (Geographical Information Systems), WMS, RFID, Internet and online customs clearance were largely driven by customer demand. Shipping information from TMS could be imported to a Customer Relationship Manager (CRM) system, which would enable customers to track their consignments and download billing details generated from TMS via each provider’s web portal. However, the literature also found barriers from high IT implementation and maintenance cost, as well as internal staff’s resistance to cope with new IT systems and processes.
The connectivity between FMS, TMS, WMS, CRM and Accounting are fragmented, with lack of real-time information access to key stakeholders, resulting in bullwhip effect (Mason et al., 2003). Direct data access between systems is often connected using abstract database drivers such as Open Database Connectivity (ODBC) and Java Database Connectivity (JDBC). A case study in a global chemical company conducted by Xiong et al. (2012) demonstrated the utilisation of ODBC and JDBC to provide point-to-point integration of supply chain applications. However, not all applications can be easily be integrated using ODBC, according to Shafiei et al. (2012), collaboration between systems are made more difficult as vendor-specific Enterprise Resource Planning (ERP) applications do not allow full integration with rival applications (Figure 2.1). As the result, more complex interface wrappers are required to provide interface between local supply chain systems, which are not always available to all parties, therefore, creating fragmented connections at a global level.
He et al. (2009) discussed the benefit of collaborating GPS location from FMS to help improving the tracking feature of RFID systems, however, the proposed solutions are too closely coupled with the existing EPCglobal standard and do not allow for other standards such as NPC and UID to be easily introduced. The proposed RFID/GPS solution also assumed that all parties, including manufacturers, warehouses and port terminals have to conform to the same infrastructure and EPCglobal standard. In the real-world, however, not all parties would like to conform to one standard, especially EPCglobal.

During peak season, many large scale logistics operators would outsource their warehouse and transport related work to third party sub-contractors (Ronen et al., 2001). These sub-contractors are usually small operators who do not have the resource to purchase and maintain RFID infrastructures. Thus, the shipments visibility would be lost when third party sub-contractors are utilised to manage inventory during peak season, resulting in inaccurate recording of inventory (Lee et al., 2006).

2.2.1 GPS Devices

Global Position System (GPS) is a satellite-based navigation system that comprises of a network of satellites (27 satellites in total, 24 in operation and 3 for backup) placed into orbit by the U.S. Department of defence (Kumar et al., 2002). For a GPS receiver to determine its location during start up known as time-to-first-fix (TTFF), trilateration calculations are performed that require 3 or more known satellite positions (Lehtinen et al., 2008). In the early adaption in transportation and logistics, Orchid Telematics (Ford, 2001) proposed a solution to capture and store GPS data using in-vehicle GPS receivers and GSM modems to transmit GPS positions to a proprietary database via SMS messaging services. The fleet operator can also request real-time positions, by sending a SMS poll from FMS to the trigger in the in-vehicle GPS receiver to instantly release all GPS data stored in memory (Lamminen, 1999). SMS was replaced by General Packet Radio Service (GPRS) to improve the responsiveness between the FMS and the GPS receivers. Hasan et al. (2009) proposed a real-time GPS system that utilised General Package Radio Service (GPRS) to transmit GPS data to provide cost saving and responsiveness (Tseng et al., 2006) compared to the SMS service.
The issue with convention GPS receiver is its inability to determine TTFF or provide an accurate position when poor GPS signals are received (Clegg et al., 2006). This usually occurs in the city, where GPS signals suffer from multipath propagation when signals bounce off tall buildings and are weakened as they pass through walls or tree cover (Goel et al., 1999). To overcome the reception issues, large external GPS antenna, or additional GPS antenna were fitted to the vehicle to improve the GPS receiver’s performance (Bevly et al., 2006). However, these types of installation are extremely inconvenient and costly to the operators, since they must be hard-wired to the vehicle. In addition to the extra cost of installation and removal of external GPS antennas and GPS receivers, the fleet operator will also need to deal with the down-time created by each installation and upgrade. This is even more apparent when dealing with sub-contractors and/or owner operated drivers who only work during peak periods.

2.2.2 Assisted Global Positioning System (A-GPS)

For many years, manufacturers of smartphones have been working on improving the efficiency of GPS receivers embedded in their smartphones. Technologies such as compass, accelerometer, gyro, Bluetooth, Wi-Fi, 3/4G modem, and Assisted Global Position System (A-GPS), are being utilised to further improve the accuracy and locating speed of the smartphone (Paek et al., 2010). Software developer can easily access the smartphone peripheral using Application Program Interface (API) supported by the smartphone operating system (Hynes et al., 2011). The high speed modem, large storage capacity and computing power available in today’s smartphone (mobile host) will ultimately transform what was once a proprietary and legacy device, such as an in-vehicle GPS receiver (Thompson et al., 2010), into a scalable, low-cost, mobile virtual appliance that exists as one of the embedded components in smartphone devices (Want, 2009).

Early GPS receivers can take up to 12.5 minutes to TTFF. This is due to each GPS satellite broadcasting its orbital information timestamp every 30 seconds (50 bits per second). It can take up to 25 or more broadcasts before the GPS receiver can locate the current positions (Dana, 1997). In order to reduce the TTFF, Assisted Global Positioning Systems (A-GPS) are utilised. A-GPS receivers are also much simpler and cheaper to be manufactured than traditional GPS receivers, they are consider a standard feature in today’s smartphones. Instead of totally relying on live timestamp broadcast from GPS satellites; A-GPS estimates
its position roughly from the satellite timestamp, then utilises A-GPS servers embedded inside mobile station, which download the orbital information from the GPS satellite and store it in the database, embedded inside mobile stations (Kaplan et al., 2006). The orbital information stored in the A-GPS servers can then be transmitted to the A-GPS receiver via mobile data network such as GPRS, 3G, and LTE, or even via Wi-Fi. Zhao (2002) compared various types of position systems based on 3G mobile data network. In general, the transmission speeds of the mobile data networks are much faster than those from the GPS satellites, thus the orbital information can then be retrieved much faster using A-GPS receivers.

2.2.3 Mobile Virtual Appliance GPS

Most logistics vendors today often utilise a rugged PDA, with built-in A-GPS, GSM/3G Modem, Barcode and RFID scanners to capture delivery details including name and signature of the recipient (Napolitano, 2011). Since the PDA device does not need to be hard-wired to the vehicle, the data can be synchronised with TMS in real-time over a wireless data network or offline via a USB interface, thus, providing flexibility and portability to the fleet operators, especially when they are dealing with sub-contractors. With newer and faster PDAs being released to fleet operators, many of them have invested heavily on early devices and infrastructure often find themselves stuck with out-dated, high maintenance legacy solutions that cannot be easily interface with newer solutions. Therefore, the challenge remains for industries across the supply chain to collaborate information stored on current platform and infrastructure with out-dated legacy solutions. Rudolph (2009) mentioned encapsulating mobile phone configuration as a virtual appliance, so that it could be easily deployed across the cooperative network. However, in supply chain operations, the virtual appliance will need to incorporate intelligent sensors such as GPS, accelerometer and optic sensors from heterogeneous devices.

2.2.4 Current work flow

Current research on RFID and GPS systems are largely based on the assumption that manifest will be dispatched in real-time (Yun et al., 2012). GPS data obtained from FMS are underutilised, in many cases, transport operators in supply chain firms only use historical data to resolve billing issues and audit driver working hours. As the cost of mobile data
becomes more affordable, there are increased incentives for transport operators to utilise real-time GPS data in the area of:

- Automatic alerts prior to applying extra charges (detention)
- Real-time job updates
- Key Performance Indicator (KPI) and benchmarks
- Actual versus estimated arrival and departure times
- Exception alerts for delayed deliveries
- Trigger predefined processes

The current linear approach to supply chain systems current integration means that FMS systems containing critical GPS data do not have the understanding of “systems presents”, therefore, the system are unaware of current time and location that other supply chain systems are trying to monitor. Therefore, a real-time data analyser is required to monitor data stream and device status so that critical transactional data can be interpreted and routed back into the required supply chain (discussed in Chapter 5).

2.3 Utilisation of Integrated Logistics Systems

Most logistics providers underutilise their FMS, by not collaborating the information obtained from the FMS to other systems (Mason et al., 2007). In contrast, most FMS are used to generate Key Performance Indicators (KPIs) for contract work and validating the number of hours worked by each driver. In some cases, GPS data are used to provide Proof of Delivery (POD) by showing that the vehicle was at a certain delivery location at a certain time (Cleary, 2000). However, current location-based PODs are inadequate, because it doesn’t record what was delivered and who was the recipient. Thus, most transport operators also rely heavily on electronic handelds as their primary source of capturing electronic PODs.
2.3.1 Supply Chain Finance

Due to their terms of trade, most small to medium logistics operators in Australia often required large amounts of cash flow to fulfil their financial commitments. Average terms for their debtors are between 60 to 90 days from the date of invoice, but only 7 to 30 days for their creditors, such as sub-contractor and owner operated drivers. Thus, most small to medium operators depend on debt factoring facilities, in which a financial institution would fund up to 70% of their actual invoices created and the 30% remainder, also known as retention are paid when their debtor payments are made (Klapper, 2006).

Supply Chain Finance (SCF) described a holistic arrangement between a commercial bank’s lending models to improve cash flow of supply chain operators, by providing factoring facilities (Popa, 2013). Wang et al. (2008) suggested that SCF is a nonlinear and complex system with multi-layer that require commercial banks to have a strong integration between supply chain systems in order to mitigate risks. For this reason, it is critical for the financial institution which is providing debt factoring facilities to have easy access to their borrowers’ financial records. All financial data generated from TMS are often imported into an accounting suite, such as MYOB (http://myob.com.au) via a Comma-separated Values (CSV) or Tabbed-separated Values (TSV) file. The financial details in an accounting suite can be easily audited by an external accountant or auditors from financial institutions (Pecchiar, 2012).

2.3.2 Traditional Supply Chain Systems

Electronic Data Interchange (EDI) is used to provide interface for more than 90% of suppliers to Australian supermarkets and retailers (Mackay et al., 2003). Banerjee et al. (1994) described the mechanic and workflow of EDI systems. EDI provides a platform for scan packing logistics in Australia for compliance to GS1 (http://www.gs1au.org/) and European Article Number (EAN) standard (Mo, 2008). Lee et al. (1999) suggested that EDI-enabled supply chain can significantly increase inventory turnover and at the same time provide reduction to stock-outs. According to the case study presented by Johnston et al. (2012), internet based Electronic Commerce (EC) EDI could provide and simplify
connectivity to non-EC-enabled suppliers. Unfortunately, at the same time, there were resistance to adapt EDI in some of the SMEs, which proved to be an issue for many large retailers (Benbasat et al., 1995).

Rhee (2012) describes in detail the communication processes between importer and exporter and the supporting services including customs clearance, freight forwarding, international transportation, insurances, banking and finance. According to Rhee, there are different types of government agencies that are assigned to manage certain commodity trade with their own policies. Thus, it is important to acknowledge that there are many types of supply chain processes and systems that exist in today’s global supply chain. Many supply chain systems can also co-exist within the same infrastructure and platform. Pawar et al. (2000) highlighted that there are issues associated with different EDI standards in the management of electronic supply chain, due to the demand generated between trading partners. Mak et al. (1999) studied the approach and challenges in integrating traditional EDI system using Value Added Network (VAN) with internet based EDI to provide a platform to connect retailers and suppliers together (Presutti Jr, 2003). The study identified the following issues (Figure 2.2):

- Manually processed Purchase Order (PO) to non-EDI supplier via post or fax, thus, causing delay to inventory replenishment.
- Re-entry of delivery dockets back into the non-EDI suppliers’ proprietary systems causes data integrity and mismatch issues which in turn causes systems inaccuracy, therefore, increasing the costs to the supply chain operation
- Smaller suppliers do not have enough technical knowledge to operate EDI applications.
- Lack of interoperability for different EDI translators to work with business applications.
- High setup cost to establish and maintain VAN connectivity, EDI translator, application and handheld scanner (Sohal et al., 2002).
There are different types of systems, processes and infrastructures, including data capture devices such as PDA based barcode, QR code and RFID scanner that exist as components to WMS and EDI systems (Shamsuzzoha et al., 2013). Each data capture device will have its own proprietary operating system and data capture applications that are specific to each client’s requirements. Since multiple devices have to co-exist together within the same network, this increases the complexity of the IT network and platform configuration in order to avoid conflict between different applications and devices. Two supply chain information systems, SAP APO and Supply On, were compared by Goswami et al. (2013). They found that both systems demonstrated the ability to support information visibility, however, their utilisation is different within the supply chains. Meanwhile, Arli et al. (2013) reported significant cost reduction to Supply Chain Collaboration (SCC) process of Woolworth Australia from the utilisation of an internet based EDI ordering system.

### 2.3.3 3PL Distribution Centre Based System

Sohal et al. (2013) discussed the growth of outsourcing third-party logistics (3PL) in Australia and the Asia-Pacific region, in which cost saving, reduction in capital investment, facility and human resource are the key motivation behind the growth. Chen et al. (2012) emphasised that while EDI is used to fulfil many supply chain information sharing function in the area of forecasting and order batching, many organisations are considering switching
to Extensible Mark-up Language (XML), as part of the process to improve supply chain information collaboration between supplier, manufacturer, retailers and the greater global supply chain audiences.

Figure 2.3 Components of EC/EDI relationship, source (Roberts et al., 1998)

According to Zentes et al. (2012), DistributionCentre (DC) in supply chain operations can operate in multi-mode roles, from providing inventories storage to cross-dock facility. Moreover, efficient information process is of central importance in collaborative supply chain, in which new data collaborations technologies such as data warehousing, webEDI, RFID and internet applications can be leveraged to provide real-value to current supply chain operations. Gunasekaran et al. (2005) studied the benefit of build-to-order supply chain framework (BOSC) with Dell, BMW, Compaq, and Gateway. However, the BOSC framework is limited to RFID technology. Govindan et al. (2013), suggested that due to the specific client’s requirements for each warehouse process, such as receiving stock into inventory, issuing orders, and daily stock take, have to be executed with a dedicated mobile device and applications for each client. Therefore, training and inducting low skilled warehouse staff to conform to the correct process and workflow with the added burden of executing a mobile application will always be challenging. Gopalakrishnan et al. (2012), highlighted the importance of organisation culture to encourage employee to adapt to technological change in sustainable supply chain in British Aerospace (BAe) Systems.

It is also just as challenging to introduce new processes to existing warehouse operations, because the entire training and induction process have to be repeated, therefore, making the entire operation extremely rigid. Figure 2.4 shows the role of the distribution centre with different workflows for the same product with different retailers. The distribution centre will also have to handle multiple workflow and technology requirements for both export and import customers.
2.3.4 RFID Infrastructure

RFID was first conceived in World War II. Research and development in the late 1990s showed that it was one of the most promising technological innovations, with the potential to increase supply chain visibility and improve process efficiency (Roberts, 2006). However, its wider application became acceptable to supply chain in mid-200. RFID is a reliable identification technology, but there are inherent problems as a reliable identification technology. Zhou (2009) modelled item-level information visibility through reduced randomness, as a function of the scale of the information system, the distribution of the sample space, the control variables and the production functions. In view of the security and privacy issues in RFID, Solanas et al. (2007) designed a cell-based architecture with a specialised protocol which the tag readers co-operated in order to conduct tag identification in a private and scalable way. Lyu Jr et al. (2009) utilised RFID with a quality assurance system to detect, and prevent quality problems by allowing on-site staff to monitor complicated variations in production process by handling numerous possible abnormalities.
simultaneously. Wang et al. (2010) studied 133 manufacturers in Taiwan and developed a range of determinants for RFID adoption in the manufacturing industry. These efforts generated crucial engineering knowledge to assist supply chains to develop RFID systems for their particular environment.

In the last decade, RFID technology had been utilised as a medium to facilitate track and trace functions with passive RFID being the low cost option for replacing bar coding in the Supply Chain Management (SCM) realms. While RFID technology provides visibility and inventory tracking functions within warehouses, it does not provide the same visibility once the products leave the warehouse or are in transit between warehouses. Location based systems such as GPS can provide visibility for shipments in transit, therefore, it improves the accuracy of the track and trace functions within the supply chain network.

RFID Technologies were considered to be disruptive innovation (Krotov et al., 2008). In many instances disruptive technologies such as RFID are considered inferior to mainstream technologies (Adner et al., 2005). Barcode technology is an established mainstream technology that is still evolving (Soon et al., 2011). Many supply chain providers remained determined to continue to utilise barcode technology over RFID. Since RFID is considered to be a new technology, it will ultimately require further investment in training, IT infrastructures and the ongoing purchase cost of RFID tags. Although the key feature of RFID to have the ability to scan multiple items without line of sight as opposed to convention barcode system (Tsai et al., 2010), there are constant issues with readability and compatibility of tags across global supply chain networks (Kim et al., 2010). According to Schmitt et al. (2008), unlike retail chains which tend to adopt EPC standards readily, the automotive industry utilised RFID in a close-loop proprietary environment. Products that are embedded with RFID can be tracked at item level; there are security and privacy concerns to unauthorised access to the RFID tags (Slettemeås, 2009). Clarke III et al. (2008) suggested that RFID data that are stored in Object Name Server (ONS) that are accessible via the internet could be potentially accessed and associated with personally identifiable information further raising privacy concerns for consumers. Information stored inside RFID tags can be overwritten by computer virus and malware (Leavins et al., 2013). Furthermore, Electronic Magnetic Interference (EMI) from RFID readers at maximum power, could have interference with medical device such as pacemakers and Implantable Cardiac Defibrillators.
(ICD) (Zhou et al., 2010), potentially creating Occupation Health and Safety (OHS) concerns to both supply chain operators and retail consumers.

In many cases, RFID technologies are being implemented in parallel in a different subnet with existing rigid IT infrastructure that has been largely based on client-server solutions that are usually coupled with complex cooperative Virtual Private Network (VPN) network and IT infrastructure that are difficult and costly to maintain. In recent years, due to greater demand for bandwidth and high availability, many supply chain firms have opted to reduce the cost of maintaining workstation and outsource their datacentres to third party data centre providers. Datacentres also provide many redundancy layers, with respect to climate control, internet access, electricity and security access, thus, ensuring that the IT equipment is kept in their optimum operating environment to reduce the risk of equipment failure. Private VPN is utilised to provide connectivity from the datacentre to each branch and warehouses. However, the cost of maintaining datacentres and complex end-points such as private VPN are very expensive and often require expert knowledge in maintaining such infrastructure (Guinard et al., 2011).

Earlier applications of RFID to supply chains were focused on warehouse management. Chow et al. (2006) designed a resource management system that integrated RFID, case-based reasoning technique and programming model for forklift route optimization. The system increased operational efficiency by retrieving and analysing useful knowledge from a case-based data warehouse solution. Poon et al. (2009) introduced RFID into bar-code-based or manual-based warehouse management systems, and tried to solve problems in daily operations of inventory level, locations of forklifts and stock keeping units. The result was promising but there were issues in the range of readers. Kumar et al. (2010) studied the effect of manufacturers and retailers attaching RFID tags at the item level in a vendor managed inventory system. Although the outcome was limited by physical boundaries, they were able to show sharing of the tag price for coordination of the supply chain including manufacturers and retailers.

As the scope of RFID application is extended, the issue of infrastructure support between organisations within supply chains becomes imminent. Li et al. (2009) investigated the relationship of three factors in SCM: IT implementation, supply chain integration and supply chain performance. They found that IT implementation had no direct effect on supply chain performance. Instead, performance was enhanced through supply chain integration. Their
findings highlight the importance of RFID infrastructure design since RFID implementation is an enabler of good supply chain performance. Further evidence could be seen from Ngai et al. (2007) who studied the development of a RFID prototype system that integrated mobile commerce in a container depot. The system tracked locations of stackers and containers and provided greater visibility of the operations data. The study showed that the benefit of using RFID was to improve control processes in the container depot. In the grocery industry, Martínez-Sala et al. (2009) embedded an active RFID data tag to a Returnable Packaging and Transport Unit in order to improve efficiency and form an intelligent supply chain.

RFID enabled supply chain is not limited to commodity goods. Wu et al. (2006) explored the challenges and obstacles to RFID's quick adoption, the potential resolutions and approaches to the challenges, and the migration strategies to expand the RFID industry. Véronneau et al. (2009) explored the potential contribution of RFID and other technologies to the efficiency of a cruise corporation's service supply chain. The main finding of their research was that RFID could not achieve direct gains significantly enough on a pallet-level-tagging deployment to justify the expenditure. Lee et al. (2008) drew observations from three case studies in the service sector, and developed a complementary customer-facing model, which focused the diffusion of RFID on new products, services or infrastructure that enhanced customers’ value perceptions in order to strengthen customer loyalty.

However, expensive IT infrastructure and uncertain return on investment are the biggest concerns for many supply chain practitioners. Ustundag et al. (2009) used a simulation model to calculate the expected benefits of an integrated RFID system on a three-echelon supply chain obtained through performance increases in efficiency, accuracy, visibility, and security level. They investigated how the product value, lead time, and demand uncertainty affected the performance of the integrated RFID supply chain in terms of cost factors at the echelon level. Angeles (2009) conducted a questionnaire based survey and hypothesized from the collected data that supply chain managers planning to deploy RFID systems were alerted to the criticality of IT infrastructure issues as they braced for a likely widespread implementation of RFID in their supply chains. Wang et al. (2007) developed a supply chain management system with links to a personal digital assistant (PDA) as a construction management portal. The advantage of the system was not only in improving work efficiency
for on-site engineers, but also in providing dynamic operation control and management to enable project participants to control the whole project.

There are huge costs when adopting RFID into the supply chain. Kim et al. (2009) proposed a cost of ownership model for RFID logistics system and analysed the effect on profit of various parameter settings in order to support the decision making process of infrastructure construction. Whitaker et al. (2007) found that RFID implementation spending and partner mandate were associated with an expectation of early return on RFID investment. They found that firms with broad IT application deployment and a critical mass of RFID implementation spending had a better chance to achieve early returns. Fosso Wamba et al. (2008) tested the EPC network in a pilot project and concluded that while the technology could improve the supply chain processes, it would require a higher level of information sharing/synchronization between supply chain members in a wider strategy. Memon et al. (2010) attempted to use sensor network with RFID to track vehicles but there were network restrictions and cost issues. Tzeng et al. (2008) proposed a framework for evaluating the business value of RFID technology. They drew on the experience of five early adopters from the Taiwan healthcare industry and formulated the framework as a set of propositions based on literature, case studies and intuition. The high cost of infrastructure prohibits RFID’s application on a wider network. Lin (2009) suggested that the real cost of adopting RFID in supply chain is usually underestimated and real benefits are overestimated.

2.3.5 Large scale RFID Implementation

The National Demonstrator Project (NDP) was a large scale project, involving 13 consortium members. To ensure a high probability of success, the consortium decided to simplify the material flow process by limiting the flow to 9 product items. The system designs were incorporated in 15 use cases developed by the industry partners of the consortium. Use cases were used to describe how the business processes would work with the system (software). Several innovative process designs were developed to support data integrity of the system (Mo, 2008).

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. The timely information improved the efficiency of the supply chain.

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., 2009). 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. The consortium found that paperless delivery of pallets could be practised and 100% read rate was achieved in the transaction.

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 (Figure 2.5). Capital expenditures are limited. It would be difficult to convince these companies to invest in new technology infrastructures such as EPC. The common concern will be 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, a gap exists between those supply chain members who are fully EPC compliant 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 (Symonds et al., 2009). However, there are other RFID frameworks being utilised around the world (Jing et al., 2012). These include China’s National Product Codes (NPC) 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's largest exporter, it is important to acknowledge their views on the technology. 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.
2.4 Virtualisation Concept

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 virtualised environment, the virtual devices are seen externally as handling different functions. This is not possible under one rigid physical container (Skapinetz, 2007). Such virtualisation techniques have been used in medium to large scale information technology infrastructures, in which vendors 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). The techniques integrate the concept of Hardware Abstract Layer (HAL) which is presented to the operating system in each virtual server as its usual hardware platform (Okumura et al., 2004). Therefore, a virtual machine (VM) 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 and protection resource. Using the HAL concept, the network services are handled by a number of virtual servers (Hilley, 2009).

The management and maintenance of handheld mobile devices are one of the most challenging tasks for most supply chain industries. In many cases, it is the same reason why most supply chain firm are not willing to invest into new technologies such as RFID, this is due to:

- High cost of the unit and ongoing service cost (Hunt et al., 2007)
- Many type of operating systems and firmware versions to maintain
- Compatibility of mobile application between different devices, firmware and operating systems (Soroor et al., 2006)
- Limited remote device management, expensive onsite support.
• Handheld unit not being adaptable to changes (Arsovski et al., 2011).

2.4.1 Improved redundancy

The virtual machines data are stored in Storage Area Network (SAN) and not on the physical server (Sun et al., 2004). In the event of hardware failure, the same virtual machine can be seamlessly relocated to another physical server and restarted automatically in a few seconds (Uhlig et al., 2005). This improves the robustness of the system in operational functions and data backup (Cully et al., 2008) (Artur Caldas Sousa Monteiro, 2010). In the event in which the physical server is required to be turned off for maintenance, the virtual machine can be dynamically relocated to another physical host while it is still operating (Crosby et al., 2006). 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 (Ghiassi et al., 2003).

2.4.2 Manageable instances in isolated environments

The management of individual application hosted inside a dedicate virtual machine can reduce system dependency and improve reliability by isolating the operating environments (Fraser et al., 2004) (Figure 2.6). The other advantage is the ability to perform updates on an application without effecting other application running another virtual machine on the same network.

At a physical level, a virtual machine is nothing more than a large file that contains information related to an operating system, emulation information and application data (Garfinkel et al., 2003). Using a snapshot function, a hypervisor can quickly take a backup of the virtual machine including the state and application data that reside within the virtual machine, while the virtual machine is operating. Multiple snapshots can be taken from a single virtual machine in a timeline fashion, allowing user to go back and forward in time. The snapshot feature is extremely useful during installation, testing and deployment of an application (Watson, 2008). If there is a critical error during the installation, administrators can quickly revert back to a previous working snapshot.
Once a virtual machine has been fully configured; it can also be fully cloned with all the application data intact (Lagar-Cavilla et al., 2009). Therefore, a template of highly customised virtual application servers can quickly and rapidly be deployed in large scale over the virtual environment in seconds, hence, improving the agility and adaptability of the network.

2.4.3 Scalability and Adaptability

The consolidation of multiple virtual machines into a physical server assumes that the loads on the virtual machines will never exceed the total resource of a physical server (Kim et al., 2009). In certain applications that utilise high IO and CPU resource, such as Microsoft SQL Server, it may not be possible to consolidate many instances of such virtual machine. One way to improve this is to simply allocate an entire physical server to the high resource utilisation virtual machine. However, the only real advantage would be having the flexibility and manageability of a virtual environment without much yield with respect to hardware consolidation (Rosenblum et al., 2005). Kesavan et al. (2010) suggested that high I/O

Figure 2.6 Concept of virtualisation and hardware consolidation of multiple virtual machines into physical servers (Mergen et al., 2006).
utilisation VM can cause performance degradation to the physical host because of insufficient isolation between VMs. Another option is to cluster and load balance many physical servers into a resource pool so that it can be scaled up and down per specific virtual machine. Thus, in a high resource utilisation virtual machine scenario, two or more physical servers can be clustered together to boost the overall performance of one virtual machine. Clark et al. (2005) demonstrated the migration of an OS instance using VM clustering.

2.4.4 Virtual Appliances

Virtual appliances also known as JeOS (Just Enough Operating System) or Juice, consist of only the necessary components of an operating system to operate the application, thus, making them more manageable and secure compared to traditional VM (Webbink, 2010). JeOS are designed to emulate hardware devices and can operate inside a hypervisor (Geer, 2009). Unlike traditional VM, which IT administrators need to install and perform patches to the operating system and applications, JeOS can reduce the workload of IT administrators by providing pre-integrated, pre-test patches for the operating system and applications from a single software vendor, thus, reducing the cost and complexity of maintaining IT infrastructure. Kalakota et al. (2001) suggested that Application Service Provider (ASP) will be an important component to enterprise partnership, in which managing applications and infrastructure are outsourced, thus, creating a new market opportunity for ASP vendors.

As physical servers are being consolidated into virtual servers that are more agile and scalable, there are also further requirements for other network components to have similar agility and scalability (Kamoun, 2009). Mission critical physical network appliances such as firewalls, router and managed switches provide a foundation for any network to function correctly. If there are failures to mission critical network appliances, the entire network will simply collapse.

One method to increase redundancy to mission critical network appliances is to virtualise them as part of the virtual infrastructure. An enterprise grade firewall and router would have similar attributes to a low power server; that is the presence of a CPU, RAM, storage, network interfaces, operating system (Linux base) and application, thus, it can be virtualised and interact with other components in the virtual environments (Sapuntzakis et al., 2003).
The value of the appliance was never realised in the actual physical hardware compared to the application that resided inside the network device. The maintenance cost of each network appliances are heavily focus on the device operating system and core application, not the physical hardware (Wang et al., 2008).

All these studies clearly show the advantage of using virtual appliance to leverage virtualised systems and cloud computing. However, there are few studies conducted in the area of virtual appliances and hardware emulation for the supply chain, especially in the area of mobile virtual appliance.

2.5 Cloud Computing

Internet cloud and mobile computing had largely evolved in the past few years. Large amounts of information along supply chain, including planning, logistics and forecasting models can be shared across the supply chain cloud. Thus, enabling real-time collaboration and integration between trading partners to provide forward visibility, improving production planning, inventory management and distribution (Sanders, 2007). Real-time supply chain collaboration ensures that Vendor Managed Inventory (VMI), Collaborative Forecasting Planning and Replenishment (CPFR), and Continuous Replenishment (CR) processes are synchronised which leads to increased responsiveness and lower inventory costs (Du et al., 2012). Therefore, reducing uncertainty via transparency of information flow is a major objective in external supply chain collaboration. Kampstra et al. (2006) studied the gap in Supply Chain Collaboration (SCC). Thus, reducing the ‘bullwhip’ or ‘whiplash effect’ which cause artificial demand amplification pattern resulted from poor supply chain collaboration (Fleisch et al., 2005) and lack of real-time alignment between systems (Holweg et al., 2005). VMI means suppliers which consist of manufacturers, distributors and resellers make inventory replenishment decisions on behalf of the retailer to create leverage and efficiency across the supply chain. For each supplier to effectively manage their replenishment process and avoid out of stock, it is important they must have real-time visibility of their product inventory from their retailers (Waller et al., 1999).

Cloud computing (also known as Grid Computing) is a concept which computing is utilised as a utility. Cloud Computing refer to the delivery of application and service layers over the internet (Velte et al., 2009). Virtualisation is a method of presenting IT infrastructures and
resources so that it can be utilised as part of Cloud Computing service, this is sometimes refer to as utility computing (Padala et al., 2007).

Dhar (2012) discussed the benefit of cloud computing by outsourcing IT services to cloud computing providers. The author also discussed the future of IT services and Cloud computing that include the integration of new services with the existing ones by increasing the number of applications that utilise Cloud infrastructure and reliable global delivery models on demand.

Chang et al. (2012) provided a quantitative and accurate method for measuring the performance of Cloud Computing Business Framework (CCBF). In conjunction with OSM, CCBF combines statistical computation and 3D Visualisation to present the increase in Return on Investment (ROI) arising from the adoption of Cloud Computing by organisations.

Buyya et al. (2009) suggested that cloud technologies will need to be extended to support Quality of Service (QoS) between users and providers to establish Service Level Agreement (SLA). Furthermore, the authors suggested that future research should focus on new mechanism for management of VM to meet SLA requirements and new SDK to enable rapid creation of cloud applications.

Cloud Computing is transforming the way supply chains planning, execute and implement their IT platform and infrastructure (Cegielski et al., 2012). There are many successful business cases in Cloud Computing, Apple iCloud (http://www.icloud.com), Google App Engine (http://code.google.com/intl/en/appengine) and Microsoft Windows Azure (http://www.windowsazure.com) with pay as you go models (Vincent Wang et al., 2013). However, there are several deterrents to Cloud Computing, including: reliability, security, complexity, regulations and legal issues, performance, migration, reversion, the lack of standards, limited customization. There are different types of cloud deployment model including Private, Public, Community and Hybrid Cloud that exist today.

Rossetti et al. (2012) developed cloud based supply chain collaboration such as Cloud Computing Architecture For Supply Chain Network Simulation (CCAFSCNS) in assumed basic distribution tree structures of manufacturers, distributor and retailers. However, in a
global supply chain operation or in a cross-border manufacturing operation, the supply chain structures would also include interface to freight forwarders, transport companies, customs agencies, shipping lines and airlines. Berl et al. (2010) suggested relocating peak loads from aggregated hosts such as EPCIS server to a cloud resource to provide higher utilisation to existing resources.

2.5.1 Private Cloud

Private cloud involves typical virtualisation and hardware consolidation within the organisation resource (Zhang et al., 2010). Since private cloud is largely designed to be utilised within a single organisation, regardless if it is managed internally or externally by a service provider, it is much more customisable and configurable than public cloud (Wood et al., 2009). Private cloud also has tighter control on data privacy because data is stored locally in the virtualised environment with direct access. The entire private cloud infrastructure is also highly scalable, since any added resources will have a direct impact to the virtual environment. Lu et al. (2013) utilise IPSec to create a secure tunnel between private cloud and different end-points. However, organisations still have to purchase the equipment, thus, there are large upfront capital expenses to setup and maintain the private cloud environment. Toka et al. (2013) suggested how cloud computing could improve the efficiencies and data collaboration between supply chain function such as 3PL, transportation and warehouse operation. However, the authors suggested many aspects of cloud implementation in supply chains have not been thoroughly investigated and the full potential remains to be discovered.

2.5.2 Public Cloud

Public cloud applications and resources are made available to everyone. It is usually facilitated by service providers who offer their public cloud resource for free or on a pay-per-use model. The larger public cloud vendors such as Google, Microsoft and Amazon own and operate their infrastructure (Li et al., 2010). Users can access public cloud resources via internet web portal or APP. For security reasons, direct connectivity to the resource is not available. The key advantage of public cloud is that there are no upfront capital costs or ongoing maintenance costs (Zhang et al., 2010). Since the resources are shared with everyone in a one-size-fit-all model, it is not highly configurable to specific requirements.
Pearson et al. (2010) highlight some issues of cloud computing privacy, since the data is kept externally by the public providers; there are threats of unauthorised access of data by service providers or theft of data from machines in the cloud. According to Hofmann et al. (2010), the following are trade-offs when organisations migrate their IT into the cloud:

- **Security** – Organisations do not have any control over security policy firewall. Security is totally dependent on the service provider.

- **Interoperability** – Despite the issue to be presented for on premise host, the issue is magnified in the cloud environments. Additional interfaces and convertors may be required to transfer data between cloud applications.

- **SLA** – No SLA enforce so users will have to totally trust public cloud providers to ensure 99.999% uptime. If there are outages, there will be very limited redundancy options available (Armbrust et al., 2010).

- **Performance Instability** – Variation in performance and availability due to loads.

- **Latency and Network Limits** – Heavily dependent on the speed of each end-point. The Latency can cause issues with key transaction data therefore, it is not suitable for SCM of financial applications.

- **No Scalable Storage** – Difficult to expand complex data such as Relational Database Management System (RDBMS) and mission-critical transaction systems.

### 2.5.3 Community Cloud

Infrastructure and resources are shared between several organisations with specific objectives and goals, thus, encouraging data sharing and collaboration. The shared infrastructure can be managed internally or externally by a third party and it can also be hosted in a public or private cloud. The costs to setup and maintain the infrastructure are shared between the organisations. Community cloud enables a degree of freedom, which resources can be customised to suit the overall benefit of the organisation participants. When compared to public cloud, the costs of setting up and maintenance are higher, but it is less than private cloud because of the shared cost structures between organisations.
Marinos et al. (2009) suggested how Community Cloud avoids the dependency of cloud vendors, but at the same time enables specific standards to be implemented in hosted environments. However, maintaining acceptable QoS poses a challenge with Community Cloud due to the limited resources available to key stakeholders.

Many researchers are exploring the application of Community Cloud to smartphones. Kovachev et al. (2010) proposed a Mobile Community Cloud Computing platform to collaborate with Community Cloud services and cloud infrastructure for smartphone devices like Apple’s iPhone and Google’s Android phone. To et al. (2012), found Chinese government’s firewall policy that inhibit the access of established cloud services such as Dropbox.com and Google Docs cloud services that are used as key components in some cloud applications such as Mobile Cloud Computing.

2.5.4 Hybrid Cloud

Hybrid Cloud involves a combination of private, community and public cloud services. Each cloud service has its own entity, but such cloud services are bonded together to leverage with respect to rapid deployment, scalability, redundancy and privacy (Toka et al., 2013). This enables organisations to cater for sudden resource demand. By combining Private and Public Cloud, organisations can further reduce the level of redundancy by removing the constant demand for internet connectivity.

Zhang et al. (2009) presented a hybrid cloud model that provides workload balancing between public and private cloud. The model presented was limited to load balancing of video streaming services between cloud vendors and VM. However, Zhang failed to incorporate real-world constraints such as bandwidth availability at each end-point.

Sotomayor et al. (2009) proposed a management of a virtual infrastructure resource pool using OpenNebula and Haizea, instead of a traditional Hypervisor interface and API. The aim of such implementation is to enable different types of resources to be managed in a flexible plane for both local and private cloud resources. However, the authors only discussed the utilisation of GNU/Linux VM. The outcome could have difference if other operating systems such as Microsoft Windows base was utilised and high availability applications such as SQL database server were included in their proposal.
2.5.5 Mobile Cloud Computing

As smartphone, tablets and mobile computing technologies evolve, they are coupled with intelligent sensors such as GPS, camera, accelerometer, thus, enabling users to have improved intuitive experiences with their smart devices (Figure 2.7).

Kottari et al. (2013) described the concept of Mobile Cloud Computing (MCC) in which intensive computing tasks are performed using cloud computing coupled with the interface of smartphones or tablets. Mohiuddin et al. (2012) explored the utilisation of intelligent sensors to further increase the capability of smart devices that enable community-sale sensing applications. According to the authors, the challenges imposed on MCC includes, the limitation of existing operating systems and managing offline processes that incorporate establishing usable QoS at connection end-points. Zhu et al. (2011) studied on Multimedia Cloud Computing also mention that MCC can simplify the maintenance life cycle of mobile devices, at the same time increases the devices’ battery life by the redistribution of the computation to cloud service. The studies also further highlight issues with device
heterogeneity and interoperability (Figure 2.8). Samimi et al. (2006) proposed Mobile Service Clouds in which a service gateway is used to redirect the mobile device to the nearest proxy that redistributes the configuration and service path to the mobile device, to handle disconnection issues and maintaining QoS. Although the proposed Mobile Service Clouds can assist the performance of QoS it is not suitable for SCM application, which in the case of disconnection, data from mobile sensors need to be stored inside the mobile device memory and resynchronise to the cloud server upon reconnection.

There are very little studies done in creating virtualisation platforms for smartphones and PDA devices, to provide hardware consolidation and the ability to run multiple virtual machines concurrently, as demonstrated on both desktop and server based hypervisors. VMWare Horizon (http://www.vmware.com/products/desktop_virtualization/mobile/overview.html) can isolate corporate and personal environment, by providing isolation and customisation via device group policy management. Barr et al. (2010) went through VMWare Mobile Virtualisation Platform (MVP), in which cooperate applications and database cloud can be isolated and managed over employee-owned devices. Chen et al. (2010) utilised VMWare hypervisors to virtualise the Android mobile operating system, so that the VM can access the captured image of the physical device using Network File System (NFS) protocol. However, the issues with such implementation require high utilisation of network bandwidth to control the VM, resulting in reduced battery life. Furthermore, all the MVP approaches studied are restricted to the Android based operating system. Therefore, they are unable to simultaneously operate other mobile applications from different operating systems, such as Apple iOS, Symbian, or Blackberry. Moreover, current research into MVP technologies resembled group policy control rather than true virtualisation. The issue of hardware abstraction layers (HAL) remains unresolved. There are gaps that exist between mobile applications and the operating systems that manage the legacy devices. (Figure 2.8)

Currently, there is no universal access to the device peripherals other than using API from device SDK. One of the biggest challenges for most mobile application developers is managing different mobile application SDK and development library in various operating systems with different device profiles. In most cases, mobile software developers that specialise in SCM consist of a very small group of programmers. Therefore, they only have enough resources to maintain and support a small range of compatible devices.
2.6 Software, Platform and Infrastructure Model

Software, Platform and Infrastructure (SPI) are sometimes referred as XaaS, which the collective terms “X as a Service” or “Anything as a Service”. It is used to describe cloud computing services that are delivered over the internet rather than provided locally onsite (Xu, 2012). In general, XaaS are largely based on Pay-Per-Use, thus, eliminating capital cost of purchasing IT infrastructure and ongoing hardware maintenance (Stanoevska-Slabeva et al., 2010). Users are charged based on the volume of transactions, the amount of data transmitted and the number of hours utilising the XaaS resource. Figure 2.9 highlights the relationship between different XaaS services vendors, developers and end users.
2.6.1 Infrastructure as a Service (IaaS)

IaaS refer to the responsibility of the infrastructure is outsourced to the service provider. The service provider not only owns the equipment but will also be responsible for ongoing maintenance of the infrastructure (Leong et al., 2010). The users would interact with a service provider via a web portal dashboard, in which they can monitor their resource utilisation and customised their environment profile to optimise the performance of their application with degree of flexibility (Namjoshi et al., 2009). With IaaS, the consumers have a choice of operating system, middleware and application they would like to install on the IaaS and IaaS provider does not manage the users at runtime level. Therefore, it is the responsibility of the users to maintain and update the operating system, middleware and application. IaaS is often offered as a horizontally integrated service that includes data replication, snapshot and backup service, as well as administering network and firewalls management (Khajeh-Hosseini et al., 2010). Paladi et al. (2013) discussed security models based on trusted computing as a method of securing IaaS.
2.6.2 *Platform as a Service (PaaS)*

PaaS provides the capability for users to outsource the management of their hardware, operating system, middleware and runtime environment. PaaS provider such as Google App Engine and Microsoft Azure enable application developers to host their applications that have been written with the PaaS providers’ API (Lenk et al., 2009). Since the API providers are high level and rich in function, this enables application developers to quickly test and deploy their products at a fraction of the normal costs, without having to worry about infrastructure, operating systems and storage. Somorovsky et al. (2011) and Ristenpart et al. (2009) discussed the vulnerabilities of a well-known PaaS provider such as Microsoft's Azure and Amazon's EC2 services.

2.6.3 *Software as a Service (SaaS)*

SaaS enables consumer to have access to software that is provided by service providers. In most cases, the applications are accessed via a web portal (Cusumano, 2010). The consumer does not have any control over the infrastructure including server, network, storage, operating system and core application configuration. In many cases, SaaS users are limited by user interface (UI) options since the UI options are a component of a framework that is hosted in PaaS (Tsai et al., 2010).

SaaS provides a cost effective delivery of key business solutions including Customer Relationship Management (CRM) and Enterprise Resource Planning (ERP) (Torbacki, 2008). The SaaS model is also becoming standard for the way in which SMEs license their applications on a pay-per-use or a month-to-month basis. Applications such as Microsoft Office 365 includes an offline Office 2013 desktop, which the licence is paid monthly rather than a once off payment with ongoing maintenance and upgrade support (Karthik et al., 2013). Jiang et al. (2012) suggested that malicious attacks to cloud service could potentially lead to mass deployment of SaaS driven internet agents. XaaS pay-per-use model can reduce the capital cost of IT investments significantly. Studies show that security issues presented with IaaS and PaaS are one of the biggest deterrents for the supply chain community to participate, despite the cost saving benefits.
2.7 Network resource management

Network resource and bandwidth are very important factors in implementing a RFID network. It is not possible to assume that every RFID network device will always terminate in a perfect network work environment (Rui et al., 2012). In some cases, companies would often utilise an array of General Pocket Radio Service (GPRS), Third Generation (3G) and Forth Generation (4G) wireless network services to initiate the establishment of a new or temporary site. Recently, the viability of mobile commerce was studied with promising results using enhanced network messaging services (Samanta et al., 2010). Gunasekaran et al. (2009) presented a framework to assist wireless networks to be used in mobile commerce. Peck, (2005) discussed the uncertainty of supply chain operation when organizations are subjected to flood, earthquake or terrorist attack where fixed line communication cannot be established. However, even with GPRS / 3G wireless network, establishing static IP address is not possible, since mobile data technologies are designed to enable users to access the service from different geo-location, thus, causing the subnet to be changed and routing tables to be updated which cause the current connection to reset (Dorenbosch et al., 2001). Balakrishnan et al. (2009) highlighted the issue of non-static IP assignment to mobile phones. Signal and network resource load from 3G network may not be enough to sustain a real-time network such as RFID (Yang et al., 2009). It is also not suited to RFID implementation which focuses strongly on fixed static public IP address, in which network address translations (NAT) are required to access specific applications (Yang et al., 2010).

As mentioned in section 2.4 and 2.5, with the aid of virtualisation and cloud computing, supply chain IT infrastructure can be consolidated into physical devices reducing the cost of ownership and provide better redundancy support (Sultan, 2010). Cloud computing can further improve the performance of a RFID network by centralising information such as EPC-IS data within the cloud instead of being behind a private firewall (Cao et al., 2011). Thus, improving the performance of data integration processes and reducing the dependency to endpoint links. This poses a challenge for newly developed estates, in which access to high speed broadband are not always available and organisations often are required to rely on GPRS / 3G / 4G wireless networks, which do not always provide adequate and reliable performance for cloud computing. Kumar et al. (2010) studied in mobile cloud computing suggested that services outages that occur in poor reception areas is largely due to TCP overhead (Holland et al., 2002).
To connect sensors such as RFID to a hosted EPC-IS cloud services, a reliable, stable connectivity are paramount for any hosted service to function correctly and effectively (Figure 2.10). Since each physical device will transmit event data directly to the cloud services, high-speed broadband is required. In the case in which wireless mobile data networks are utilised, it may not always be possible for all the RFID sensors to transmit RFID events to the hosted service reliably. Therefore, a new method of transmitting RFID events data is required to lower the overhead of TCP when the connections are subjected to poor connectivity.

![Image of Comparison between cloud service and private end points](image_url)

Figure 2.10 Comparison between hosted cloud service and private end points

### 2.7.1 Dynamic DNS

Dynamic DNS, such as DynDNS ([http://www.dyndns.com](http://www.dyndns.com)) can provide constant DNS update services, which public static IP addresses cannot be obtain, such as GPRS, 3G and 4G mobile networks. Tsietsi et al. (2008) studied in mobile peer-to-peer SIP agents
suggested that Dynamic DNS could be used as part of host discovery services. Therefore, Dynamic DNS service can be used to resolve hostnames with non-static IP addresses that reside behind mobile data network. However, Dynamic DNS service is a subscription service that is managed via a secure login on both the provider and client (Cachin et al., 2004). Atkins et al. (2004) discussed some of the challenges with securing Dynamic DNS. If Dynamic DNS server is attacked and the mapping of the hostname and IP address could be altered via the web-portal service or from another device with the same Dynamic DNS subscription details, this raises the concerns with respect to data security and integrity obtained from sites that are managed using Dynamic DNS services.

In a scan packing logistics operation, if the Dynamic DNS subscription account is hacked, it could lead to potential financial loss between trading partners, in which the order content ASN and SSCC are intercepted and altered by disguise servers hidden inside the Dynamic DNS A-record. Furthermore, changes to IP connection do not occur instantaneously, therefore, hosts that utilise Dynamic DNS may not appear to be connected to the network.

Consideration in regards to packet lost, ping and jitter delay must be taken into account when designing and implementing a real-time system, such as RFID enabled system. Using dynamic DNS such as DynDNS.org may not be feasible because the IP renewal is not real-time, there are delays between each renewal, which may cause aggregate queries to timeout.

2.7.2 Anycast

Anycast is the ability to deploy the same server across multiple nodes with different networks that are spread over different geographical locations. A global load-balancing DNS service is embedded inside Anycast that is invisible to the DNS servers. Since each node advertises the same IP address, if one node is taken offline, it will stop sharing the same IP address and the traffic will redirect to alternative servers nearby. Since the performance of XaaS depends on the server geographical location, the further the XaaS is away from the targeted user, the less responsive it will be. Many IaaS providers offer Anycast with data replication and clustering between IaaS servers across different geographical locations to improve and increase the performance and redundancy of the IaaS. According to Hashmi et
al. (2012), Anycast can be used to isolate malicious attacks such as Denial of Service (DoS). However, the security of the DNS server compromised by malicious attacks could compromise the data security and integrity of XaaS servers (Partridge et al., 1993). Wu et al. (2001) concluded that Anycast routing in mobile ad hoc networks consume too much overhead and therefore, require further exploration.

2.8 Tracking Methods

Jones et al. (2005) proposed the “Fast lane” for Metro Group that utilised RFID, offers improved shelf replenishment and automated checkout, which customers are able to checkout without emptying their grocery cart. Jones proposal may not be currently possible, since it is totally dependent on RFID technology. Twist (2005) suggests in reality, RFID will not provide complete supply chain visibility due to the costs incurred from the tag and RFID reader limitation. The author also suggested that barcode and RFID will need to coexist for the foreseeable future. Recent survey evaluation of RFID checkout was mixed (40 in favour, 53 neutral, and 62 opposed) with respondents appearing to trade-off changes against less waiting time in queues (Dean, 2013). Unlike barcodes, RFID tags do have some disadvantage, such as the costs associated to the tags, which is currently too expensive to be incorporated as part of a manufacturing process of packaging and lack of standardisation between different types of RFID tags (Harney, 2009).

Another drawback with utilising RFID in a retail chain is the overflow of information received by the tags. Since each tag individually identifies each item instance, unlike barcode which only identify the Stock Keeping Unit (SKU). Krohn et al. (2005) discussed the drawbacks of individually tagging products using RFID and introduced a method of pre-processing RFID tags to improve data processing.

In a retail environment, it is not plausible to assume that a typical shopper would purchase exactly everything from their shopping list. This behaviour can be describe as “Random pick”, meaning that the system does not know in advance what each shopper would choose. Furthermore, it is impossible to assume that every shopper would carry a smartphone or any compliance data capture device. Thus, for a smart shelf to effectively function in a retail / supermarket environment, all the technologies involved must be hidden from the user and operate ubiquitously.
Mobile checkout APP is also another emerging method of self-checkout, in which customers can scan the product barcode and make payment through a smartphone (Eastlick et al., 2012). However, the retailer cannot assume that all customers would be equipped with a compatible smartphone. Therefore, a manual checkout procedure will need to be included. Thus, supply chain operations, including retail, cannot solely depend on a single technology platform. Moreover, the entire system will need to function ubiquitously, in which different type of sensors can autonomously function together to achieve a common goal. The user will only need to worry about the physical interaction to the products on the shelves without any consideration to the checkout procedure.

2.8.1 Image Processing

Today’s digital video cameras are becoming smaller, clearer and more affordable than ever before (Ochola et al., 2013). However, according to Napolitano (2011), rugged mobile data capture device manufacturers still argue that their devices are more rugged and scan/capture data more efficiently than any smartphones produced today. Smartphones that are available today are usually equipped with a least one digital camera with capability to capture photos and video. However, as mobile computers become increasingly more powerful (Kato et al., 2010), they can also be used to decode binary data that are embedded with in an image file or video stream (Walling, 2012). Moreover, with the increased availability in open source SDK library such as ZXING Zebra Crossing (https://code.google.com/p/zxing/), ZBAR (http://zbar.sourceforge.net/) and commercial API such as OnBarCode (http://www.onbarcode.com/), application developers can easily and efficiently utilise the available API decoding 2D function in their applications.

2.8.1.1 One Dimension Barcode

EAN and UPC (Universal Product Code) barcode (Figure 2.11) are widely utilised in a retail environment (Klabusayová, 2013). Scornavacca Jr et al. (2006) studied the utilisation of EAN and UPC barcode standard with mobile commerce (m-Commerce) market. Unlike RFID, barcodes do not generally uniquely identify an individual item, but classify it as SKU (Stock Keeping Unit). Gaukler et al. (2007) proposed an analytical model for item-level RFID for retail supply chain. Thus, the classification function of a barcode is enough to fulfil the requirement of most retail chains checkout and inventory management. Youssef et al.
(2007) proposed a smart barcode detection system that enables damaged barcodes to be read with a degree of success. Ohbuchi et al. (2004) developed an algorithm to process both EAN and QR code using a smartphone. The performance of the algorithm is 66.7 frames per second for EAN barcode and 14.1 frames per second for QR Code, which is largely dependent on the type of sensors and CPU speed of the smartphone.

2.8.1.2 QR Code

QR code (Figure 2.12) was developed by a Japanese corporation Denso-Wave in 1994 (http://www.denso-wave.com/qrcode/index-e.html). It has been widely used in Japan. QR Code is also known as 2D barcode, Kato et al. (2010) discussed the characteristics of different types of two-dimension barcodes that can be scanned using smartphones. Initially, QR code was used for tracking parts in vehicle manufacturing. It is now being accepted in a much broader context, including commercial tracking applications and convenience-oriented applications aimed at mobile phone users (also known as mobile tagging).

In a supply chain environment, information such as product code, serial number and production date can be encoded using QR code. QR code is essentially a picture containing encoded data, which can be decoded by filtering the pixel of the image. Therefore, it can be easily captured as an image by digital camera. The main driver for developing QR code was for high speed, fast moving scanning application (Soon, 2008). It is important to acknowledge that if data were 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 a pointer to a particular web portal, where detailed information can be retrieved externally (Figure 2.18).
URL link encoded with QR code can be quickly decoded virtually on any computing device that connects to the Internet. Liu et al. (2010) utilised QR Code to create an Augmented Reality (AR) mobile English learning system, in which QR Code is utilised as a marker in the mobile application. The QR Code maker is then substitute with multimedia content. Typical mobile platforms such as Apple iPhone, Google Android and Nokia Symbian phones can easily decode QR Code using open source library. Hence, to virtualise the identification system using QR code, a smartphone with camera can be used to decode QR Code and then post the decoded data to URL or a global information server.

2.8.2 NFC - Near Field Communication

Smart phones are currently arguably the most widespread mobile computing devices. A new technology called Near Field Communication (NFC) is an extension of RFID technology. A RFID system consists of two components, the transponder, also called a contactless target (RFID tag) and the transceiver, also called a read-write-device (RFID reader/writer) (Falke et al., 2007).

The Near Field Communication Interface Protocol 1 (NFCIP-1) is defined in ECMA-340 and in ISO/IEC18092. The standards support data rates of 106, 212, and 424 Kbit/s (Knospe et al., 2004). In NFC systems, only two devices can communicate concurrently (Abel et al., 2010). They exchange data using inductive coupling and radio signals. One of the communication partners is called an initiator and has an active role, while the passive partners are referred to as targets. Both roles are always assigned, thus eliminate the issue of cross talk and over scan that exist in RFID systems. However, Uckelmann et al. (2011) questioned the true value of NFC over 2D barcode, since digital cameras are already built-
in on smartphones. Currently, mobile phone manufacturers such as Nokia, Siemens and Samsung already have NFC embedded to their smartphones (Lotito et al., 2012). Visa and MasterCard's Pay Pass already have an Android APPS that support NFC Mobile payment; which are payments that can be made by touching the Pay Pass reader with your NFC mobile phone. Leong et al. (2013) studied the impact of NFC-enabled mobile credit card systems. Hancke et al. (2010) suggested that NFC could also be used to perform item tracking since NFC facilitates ad-hoc communication between smartphones and NFC tag objects. However, achieving public support and acceptance would be required to overcome major challenges in regards to privacy, ownership and system data integrity.

2.8.3 Smart shelf

Yeh et al. (2011) discussed the utilisation of RFID in a smart shelf where RFID readers are placed on each shelf which continuously scans for products with RFID tags inside each shelf. This is extremely costly and complex infrastructure to establish and prone to many interference issues as discussed by Krohn et al. (2005), when interference is caused by many RFID readers installed in a dense setting. Angeles (2005) anticipated that one of the key technical challenges in implementation RFID will be isolating the RFID reader so that it is not “distracted” by surrounding metallic objects, such as metal shelves or belt buckled and accidentally misreading nearby RFID tags. To improve tag performance, Yoon et al. (2008) modified the tag information reading mechanisms. The experimental results showed that when the new mechanisms were applied and the initial number of slots were chosen appropriately, the performance of the modified tag collection algorithm was greatly enhanced compared with the standard tag collection algorithm.

Yong et al. (2012) proposed smart shelf with minimum utilisation of RFID readers by organising it in a cascade arrangement. However, the performance of such arrangement is largely dependent on the distance between tags and the height between each shelf, therefore, such arrangement is not feasible for a FMCG (Fast Moving Consumer Goods) retail chain.

Distance between RFID readers and tags can affect the performance and accuracy of a smart shelf. Yeh et al., (2011) showed that inventory check and stock replenishment must be manually conducted by an operator and not a mobile RFID reader. Therefore, the smart shelves are only used to track the movement of goods, between each smart shelf thus,
providing minimal value to streamline the existing workflow of a typical retail chain such as stock take and stock replenishment.

Current smart shelf systems are considered to be disruptive technology. Once the product has left the shelf, it is invisible to the entire system until the product is re-discovered at the next detection point, such as checkout. Thus, current smart shelf technology offer minimal value to the rest of the supply chain, because it cannot detect external interaction to the smart shelf, such as who picked or replenished the item to and from the smart shelf. Therefore, existing smart shelf can only operate in an open loop arrangement, where it needs to interface with other peripherals such as handheld scanners so that it can assign the items being picked to a person picking the orders.

2.8.4 3D Image Processing

Prasse et al., (2011) proposed an automated de-palletising model using RFID and 3D imaging from PMD 3D camera. By analysing the point cloud data from the 3D camera and RFID signal strength, the authors were able to reconstruct the loading configuration of a euro pallet, so that it can be unloaded using robots. However, with good data integration between trading partners, pallet configuration can be easily obtained using Serial Shipping Container Code (SSCC) lookup. In a real-world application, utilising 2D barcode, like QR code cloud ultimately improves the overall readability of SSCC and can simplify robotic applications (discussed in section 2.8.1), which is far simpler and accessable than using costly RFID and PMD 3D camera infrastructure.

Wilson (2010) investigated the utilisation of 3D cameras as virtual touch sensors. Using a pre-released Microsoft Kinect 3D camera, the author was able to detect touch recognition on an un-instrumented surface. While the performace of the proposed virtual touch sensors may not be as accurate as conventional touch screen technologies, it is accurate enough to identify touch events on a non-flat surface. Shotton et al. (2013) proposed a new method of quickly and accurately predicting the 3D position of body joints from a single depth camera with positive results.
2.9 Minimise bullwhip effect with new tracking medium

Lee et al. (1997) defined the bullwhip effect as a phenomenon where orders to the supplier tend to have a larger variance than sales to the buyer, and the distortion propagates upstream in an amplified form. Hasan et al. (2013) suggested that the bullwhip effect can be reduce for auto assembly industry from utilising CPFR for information sharing and coordination.

2.10 Conclusion of chapter

This chapter reviews technologies that are used within current global supply chains that are not optimised. Data needs to be collaborated in real-time to key stakeholders to reduce the bull-whip effect. While e-Tracking and other technologies may improve efficiency of data collaborations with key stakeholders, standards such as EPCglobal are expensive and rigid. According to Kefalakis et al. (2008), EPCglobal does not have provision for other technology stack, such as NFC. Furthermore, a high cost base makes RFID investment almost impossible to be justified (Lin, 2009). These barriers could have potential adverse effect to smaller supply chain firms which do not have the resources and capability to participate.

Successful technology adoption relies on good infrastructure design of the application environment in which the new technology system is deployed. The cost models for evaluating business case for technology deployment are based on the notion that the technology is available everywhere in the supply chain. Since the issue of broken communication path in the supply chain due to incompatibility or malfunctioning issues is ignored, performance of RFID systems in practice can never achieve the expected level of revenue. Despite various sensor technologies such as GPS, QR Code, RFID, NFC are utilised in different segment of the supply chain, the data obtained from these sensors cannot be shared collaboratively nor are they correctly synchronised to the correct stakeholders, due to the lack of interoperability between internal systems.

The literature review shows that new, virtualisation technology can reduce the cost of establishing and maintaining network infrastructure. However, currently, virtualisation technology does not extend to mobile devices for global track and trace. Application
developers are still heavily dependent on native device SDKs to gain access to built-in sensors. Thus, mobile device and data capture applications utilised in global supply chain operations remain device specific. These devices are also heavily dependent on their platform to synchronise their data, as demonstrated in ED/EDI operations.

Therefore, it is clear from the literature review that gaps exist between current identification technologies, platforms, services and hardware devices. The technology stack does not connect collaboratively nor can they be easily synchronised. Thus, a framework is required to fulfil such requirements.

The rest of this thesis identifies the issue with existing supply chain interfaces and proposes a new global supply chain framework to leverage the benefit of virtualisation and cloud computing to provide an agile and adaptable data collaboration model through various interfaces and platforms across a global supply chain network.
Chapter 3 Virtual Infrastructure

3.1 Introduction

The need for organising business on a global basis has increased supply chain activities in recent years substantially (Chauhan, 2005). A manufacturing-based supply chain contains a broad spectrum of partners including manufacturers, third party logistics (3PL), distributors, retailers and has significant uncertainty in its operations (Cucchiella et al., 2008). Such supply chains need to be coordinated by the barcode-based ‘scan pack’ technology (Pawar et al., 2000) and good IT infrastructure (Maad et al., 2010). However, the scan pack process is very labour intensive and time consuming. It requires both sides of the communication parties to scan and verify a number of packaging information. Since most scan pack systems are standalone applications, it has been an integration issue to most enterprise management systems and ERP implementations (Power et al., 2002). Scan pack supply chain information infrastructure is built on barcode identification technology, which has inherent deficiencies such as inability to identify individual items. With the trend of globalisation and customer expectations, goods are required to be identified in small batches or in some cases, individually for quality control and market segmentation. Unfortunately, there is no universally agreed system architecture of structuring that information among the stakeholders for secure access by the authorised parties.

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). In a virtualised environment, the virtual devices are seen externally as handling different functions, which are not possible under one rigid physical confinement. 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.

Virtualisation and cloud computing have been largely based on consolidation and simplifying hardware into manageable service layers. However, gaps exist in the mobile virtualisation and emulation space (see in section 2.4.5). Mo et al. (2012) discussed a virtualisation model that could utilise various sensors from smartphone and PDA mobile devices to substitute legacy native sensors. Similarly, Lorchirachoonkul et al. (2009) discussed the benefit of utilising smartphone peripherals to emulate RFID sensors in which
QR Code and GPS sensor are utilised as a virtual appliance and collaborating the tracking data into a virtualise supply chain framework.

This chapter explores the virtualisation technologies in the context of building a global integration framework incorporating mobile devices. In addition, the virtualisation “model” is tested by the design and implementation of ISA which provides interface and connectivity to isolated legacy systems used in some of the stevedore companies in the Port of Melbourne, Australia. Furthermore, the benefit of virtualisation and cloud computing with Virtual Private Server (VPS) will be discussed in details, demonstrating the benefit and scalability of leveraging XaaS model to existing infrastructure.

3.2 Devices for virtualisation

Rugged PDA used in a supply chain to capture data, such as barcode, QR code, Data matrix and passive RFID tags are also becoming increasingly more powerful. There are different types of physical devices that are being utilised to perform the same function, especially in the area of scan packing logistics, in which the decision to invest in costly rollout of ruggedized PDA is largely driven by the scan pack logistics requirements. Ruggedized PDA manufacturers such as Intermec and Symbols are constantly improving their products, thus, many of the rugged PDA and data capture device that exist today may no longer be supported or available to be purchased to replace faulty units in the future. This obsolescence problem forces scan pack providers to purchase completely new batches of ruggedized PDAs and data capture devices once every few years.

Not all consumer devices will have the sensors of the commercial device built-in. It may not be feasible for a consumer smartphone to have a laser barcode, QR code or data matrix reader, simply because there is no demand for such sensors in the current consumer smartphone market. However, there are many useful embedded devices that can be used to emulate those of commercial devices. Each embedded hardware component can easily be accessible by utilising Software Development Kit (SDK) and Integrated Developer Environment (IDE) that is especially designed for each mobile platform. For example, instead of having a laser barcode reader, consumer smartphones have a high resolution camera that could take the photo or video stream of a barcode and decode it using an image
processing library from an open source resource. Once the barcode data is captured, it is processed in the same way as those read from conventional laser barcode readers (See Figure 3.1).

Figure 3.1 Concept of emulation of dedicated commercial devices from consumer device. (Lorchirachoonkul et al., 2009)
3.3 Mobile Platform for virtualisation

The concept of virtualisation not only applies to servers and network appliances, it can also be applied to PDAs and data capture devices, such as RFID UHF readers. Unlike desktop and server hypervisors used in virtual infrastructure, current Mobile Virtualisation Platform (MVP) does not enable mobile applications from other operating systems to operate concurrently (Barr et al., 2010). Therefore, it is not possible to operate and install multiple instances of mobile operating systems in a PDA. The restriction to MVP is not due to hardware technology constraints, but is commercial constraints that is created by the competitive nature of mobile operating system providers such as Palm OS, Google Android and Microsoft Windows Mobile and PDA manufacturers including Symbol (now Motorola), Intermec and Datalogic who do not want to work collaboratively together at the current moment.

Mobile technologies are rapidly developing. Embedded devices, such mobile HTML5 web browsers, high resolution camera, high speed modem, accelerometer, gyro and high powered processors have been introduced to consumer smart phones. The notion of using consumer mobile devices coupled with a ruggedized housing may be a feasible option for many SMEs that previously would not be able to afford and maintain dedicated commercial ruggedize devices.

3.3.1 Cloud compiler for virtualised devices

Each OEM mobile operating system such as Google Android and Microsoft Windows Phone, are designed to operate with different smartphone and tablet manufacturers, such as Samsung, Sony, LG and HTC Motorola, with different hardware specifications and requirements. The implementation and deployment of mobile applications that can provide consistent user experience and performance between different device profiles can be extremely time-consuming and challenging. These are extremely challenging when trying to develop a cross platform application. In general, developers are required to develop and maintain applications that are written in device specific language. Thus, it may not be feasible or possible for an application provider to provide specialised cross platform solutions.
It is important to acknowledge that for both virtual and physical environments, the value is in the content of the data collected, not the method or technologies used to collect the data content. Therefore, a new approach is needed to create an agile, flexible environment that is universal across different mobile operating systems and devices. Unlike conventional virtualisation techniques, which the entire mobile platform can be consolidated into virtual machines to enable it to be isolated and deployed across different mobile devices and platforms, current technologies and commercial constraints mean that mobile virtualisation cannot exist at bare metal level and need to occur from within each platform operating system.

In figure 3.2, there are many types of cross-platform compliers including Titanium (http://www.appcelerator.com/platform/titanium-platform/), Corona (http://www.coronalabs.com/) and PhoneGap (http://phonegap.com/). These mobile software development frameworks utilise HTML5, CSS3 and JavaScript languages to cross compile and deploy in native applications for device specific platforms. Using a HTML5 and JavaScript syntax, developers can rapidly create a native mobile application for iOS, Android, Windows Mobile, Blackberry, Symbian and Bade devices with access to embedded devices such as accelerometer, camera, compass, contact, file, geo-location, media, network, notification and storage. By eliminating the requirement for device or platform specific language, supply chain application vendors can easily develop and maintain their cross-platform applications so that they are available to more consumer devices, thus, reducing the cost of the overall ownership.
3.3.2 Cloud based application deployment

One of the biggest challenges to any cross-platform developer is to constantly maintain an up-to-date SDK, API and IDE for each platform. One method is to integrate a multi-platform cross-compiler with Cloud Application Store (CAS) such as Apple’s APPS Store, Google Play and Microsoft Windows Store, to compile and deploy applications to each device platform in real time. CAS is an integrated application or system component that is closely coupled to the mobile operating system. It enables users to access millions of mobile
applications that are available for free or for a small licensing fee. For paid application, CAS is also responsible for managing royalties’ income to the application developers. With cloud based application deployment, all compiling is executed externally with the latest up-to-date device profiles, including display size.

Cloud based application deployment tools such as PhoneGap’s Build (https://build.phonegap.com/) is a PaaS service that enables developers to compile and deploy their applications to CAS using HTML5, CSS and JavaScript without having to own or maintain native SDK over cloud services. The developers simply enter their CAS username, password and license key into the PGB, and select what platforms they would like to build and deploy their application and PGB will automatically compile and deploy with just a click of a button. The application project and source code can also be shared and collaborate with other PGB developers. Thus, PGB can create a cost effective application development and deployment solutions for a variety of mobile device platforms, including the proposed Mobile Virtual Appliance (MVA) approach discussed later in this chapter.

3.4 Internet Screen Agents (ISA)

In legacy systems, it is impossible to assume that all legacy system can be accessed within TCP/IP stack. Thus, the only method of connectivity is based upon native access as intended by the application. Scripting language such as ACTOOLS (http://www.actool.net) was originally designed to create ISA inside a complex online computer game, using bitmap detection from output screen. The scripting language enables access to operating system function call, such as, copy and paste variables in memory and invoke remote function call e.g. FTP, Telnet, SSH (Secure Shell), Remote Desktop (RDP) to other remote computers. Thus, ISA can be used to create an interface to legacy systems, at the same time, it can also be used to autonomously scan and extract data such as shipping schedule and container status directly from the legacy system’s screen data into TMS and WMS. In the event of data mismatch due to incorrect data being entered into TMS or WMS, the ISA can also send email alerts directly to the operators. The functionality of ISA has been investigated in a few industry applications as part of this research.

ISA are software applications that execute an automated task over the internet. Tasks performed by ISA are usually simple, structured and repetitive. Therefore, ISA can execute
tasks much faster compared to humans interacting online. Currently, most internet ISA resides within the TCP/IP stack (Rodrigo et al., 2012). ISAs are used in various ways from creating malicious and spam messages in chat rooms to providing customer service (knowledge base) to online sites (Gianvecchio et al., 2011). However, the operating model of ISA is an important element in virtualisation.

3.4.1 Integration ISA with legacy systems used in supply chain systems

In a global supply chain there are many legacy systems that do not easily interface with organisations that are unwilling or do not have the capabilities to embrace new technologies and data collaboration. According to Mark et al. (1999), data such as delivery dockets have to be manually entered into non-EDI suppliers’ proprietary systems which cause data integrity and mismatch issues between systems. Less than 5 years ago, stevedore companies in Australia still relied on dial-up Bulletin Board Service (BBS) to provide up-to-date import and export shipping line schedules to wharf cartage operators. The BBS was later wrapped inside a Java terminal, but the interface was the same.

As previously discussed in section 1.1, connectivity to legacy systems are not always possible. This is highlighted for the two largest stevedore companies located in the port of Melbourne, Patrick Ports and DP World terminals. Both stevedore companies utilise legacy systems that are isolated from the rest of the supply chain network. The only method of accessing and interacting with either stevedore systems is to manually enter data by hand into their legacy system’s interface and this is prone to human errors. Since there are no alerts available from such systems, wharf cartage operators are required to monitor each container status for changes, such as monitoring the release of customs “On Hold” status. Therefore, depending on the volume of containers processed and the level of human resources available, the container status is often monitored on a daily basis rather than on hourly basis. The time lag (usually within 24 hours) creates inefficiency to the rest of the supply chain. Furthermore, the data from the stevedore will also have to be entered manually into the TMS and WMS so that appropriate resources can be allocated to process the container (Figure 3.3).
Figure 3.3 Access to stevedores’ legacy systems are done manually.

Receiving correct shipping line schedules are paramount for any wharf cartage operation. However, this information is usually updated on their legacy systems within a few minutes before they open their container booking systems, this is referred to as time slot booking. To avoid queuing at the terminal, the time slots are spread into different time zones, so that the containers are picked up in a systematic and logical way. However, there are limited numbers of time slots available per each time zone. To maximise vehicle utilisation, the first available time zone is always in the highest demand. Using the stevedore legacy interface, known as Vehicle Booking System (VBS), each wharf cartage company enters the time slot booking screen, at the same time, in a first-come-first-serve fashion, but even if the wharf cartage operator has managed to secure the time slot, they will also need to ensure that the container they plan to pick up is available to be picked up and that they do not have any customs “On Hold” status. Any unused timeslot will incur a fine from the stevedore to the wharf cartage company, thus, it is paramount that an operator knows exactly how many timeslots are required at a specific time. Hence the strong dependency on shipping schedules.
3.4.2 ISA case study: Interface to Stevedore companies

Gaffney Logistics, in Melbourne, Australia utilised ISA to constantly scan stevedore companies, DP World (formally P&O Ports) and Patrick Ports. The shipping schedules are available 30 minutes prior to the first time-slot being available to book and there could be more than 150 containers waiting to be booked. It is important for the operator to check the latest shipping schedule to avoid over booking time-slots.

The access to the shipping schedule from the stevedores web portal or proprietary applications is a password protected interface (Figure 3.4). The ISAs used at Gaffney Logistics were developed with Microsoft Windows XP 32bit virtual machines running ACTOOLS scripting language. They perform repetitive tasks of entering username and password to the web portal or stevedore proprietary application, and navigating to the correct port and then copying and pasting the data from the terminal screen into memory before writing it to a file and then parsing it into a TMS solution code name TRANSACTION. The shipping schedules are also shared with the WMS solution for automatic scheduling of export containers for Froster Group.

![Figure 3.4 Screen shot of DP World legacy vehicle booking systems (VBS)](image-url)
3.4.3 ISA case study: Interactive Customs Service (ICS) Redundancy

All inbound freight needs to be marked and their bill of loading recorded and transmitted to Australian Customs services via an EDI or ICS web portal (Figure 3.5). At Gaffney Logistics, the information was transmitted to Australian Customs using an EDI interface with a proprietary application code named eTrack. The EDI application specification had evolved over a period of time. Hence, the eTrack EDI interface was upgraded constantly. However, there were constant compatibility issues with eTrack EDI and ICS. Thus, the ISAs were also used to automatically login to the ICS web portal and to automatically fill and submit the online bill of loading form.

Figure 3.5 Screen shot of Australian Customs ICS systems

3.4.4 Key findings from the ISA case studies

Since each ISA relies on robust internet connection to access legacy systems from within a virtual environment, ISA performances are largely dependent on the navigation speed of the legacy interface and internet bandwidth. On time sensitive tasks, such as processing the large amounts of container status checks before time slot booking or collecting the shipping schedule from each stevedores’ terminals, it may not be possible for the ISA to complete the
task in the required time. Using an API built in most hypervisors today, ISA can also have the ability to invoke other ISAs inside the network. In the event that all ISAs are busy, ISA can also automatically turn on additional virtual machines located on other networks, so that time sensitive tasks can be completed on time.

Figure 3.6 ISA embedded inside virtual machine to interface isolated legacy systems.

In figure 3.6, the key design components of the ISA are:

- **ISA Manager**: Manage, Monitor and Map the ISA instances and their physical hosts. ISAs can be hosted in consolidated virtual environments; teams of ISAs were pre-allocated to specific departments. However, as more virtual machines were added to meet new demand, the overall performance of the virtual environment begins to degrade from over utilisation. If an ISA is not being utilised, the ISA manager simply turns off the virtual machine that houses the ISA to minimise physical resources. If there is sudden
increase in demand for the ISA, then the ISA manager would automatically turn on more virtual machines to fulfil the necessary demand via the hypervisor API.

- **Task Listener:** Constantly scan and monitor the input directory for the task to be executed. If an input file is found, an input analyser is then executed, along with the input file as parameter.

- **Input Analyser:** Since there can be different types of tasks assigned to the ISA, the input analyser will parse the input file and determine the correct procedure to be executed.

- **Task Manager:** The task manager analyses the input file request and calculates the expected execution time of ISA runtime. If the estimated duration is longer than the required time, the task handler then divides the task by creating smaller input files and dispatches it to the invoke manager. If the required time is not specified or the estimated duration is shorter than the required time, then the invoke manager is bypassed.

- **Invoke Manager:** Scans the network for idle ISAs, if all ISAs in the network are busy, the Invoke Manager would send requests to ISA Manager to temporarily turn on more virtual machines. Once the virtual machine is available, the Invoke Manager can invoke the ISA on the remote virtual machine by sending an input file that is processed from the Task Handler to the remote Task Listener.

- **ISA Runtime:** Executes the ACTOOL script with the input file from either the Task Handler or the Invoke Manager. At the same time, it also produces an output file as a return variable.

- **Export Manager:** Transports the process file back to the back end and invokes updated procedures to TMS and WMS.
Figure 3.7 Overview of TRANSACTION wharf cartage TMS interface.
Figure 3.7 demonstrates the user interface of TRANSACTION TMS application, where the vessel, voyage, container number, weight, type, status and location, highlighted in dotted area are obtained using ISA from various stevedore companies in Melbourne.

Figure 3.8 Comparison of container data obtained from stevedore terminal using ISA

In Figure 3.8 Comparison of two container inspections using TRANSACTION TMS and ISA from the two stevedore terminals in Melbourne, Australia. The left is a valid inspection from DP World East Swanston Terminal, while the right is a failed inspection from Patrick West Swanston, where data mismatch has occurred between TMS and the legacy terminal system where the container number, container size, container weight and commodity type were incorrectly entered into the TMS by the client. It also shows that the container weight was under declared from the client, which could affect the equipment used to perform the delivery. The ability of autonomously detecting data mismatch in a legacy system and
sending email to key stakeholders to rectify the issues, improved the efficiency of wharf cartage operations and further reduces the amount of penalty fees incurred by the stevedore companies.

3.5 Theory of ISA with Virtual Private Server (VPS)

In a private virtualised environment, the number of ISAs that can be deployed are largely dependent on the physical host. However, in a cloud environment, the resource pools that can be made available to the users are infinitive in theory. Virtual Private Server (VPS) can be considered as a dedicated IaaS service, in which specific resources can be directly allocated to virtual machines. Unlike PaaS the user can have total control of the installed infrastructure including choice of virtual appliance, operating systems and services.

This section explores two service providers, Linode and VPSBlocks, and examines the key feature of VPS management that are critical for the supply chain to create, control and delete virtual machines in real-time via Bindings and Toolkits.

3.5.1 VPS Key Features

Unlike convention webhosting, VPS provides a dedicate resource pool that includes RAM, CPU, Storage, and data transfer package on a per month plan, any excess data transfer that are above the plan limit are charged extra. The users are given a username and password via a web portal (Figure 3.9). VPS contains many features to those of hypervisors, such as the ability to host many virtual machines with different operating systems in a resource pool. The web portal can enable users to administer each virtual disk used by the virtual machine within the resource pool, including cloning, resizing, mount and unmount virtual disk for the virtual machine. The easy to read dashboard enables system administrators to individually monitor the resource utilisation of each individual virtual machine as well as the entire resource pool. Furthermore, each virtual machine can be remotely accessed via Telnet, SSH or RDP to other Microsoft Windows operating system to enable application providers the ability manage their application without affecting the VPS resource pool. Password reset can also be activated from within the web portal, thus, creating an isolation layer between the infrastructure administrator and application providers. Most VPS providers, such as Linode (www.linode.com) and VPSBlocks (www.vpsblocks.com.au) also
provide standard add-on services such as daily snapshot, virtual disk and virtual machine cloning for rapid deployment.

Figure 3.9 showing the dashboard of a VPS provider

3.5.2 Web Services API Integration

For VPS to cater for an on-demand, scalable and agile industries such as those of supply chains, an automation process will be required to configure virtual machines inside the VPS resource pool. In the event where there are sudden requirements for virtual machines, e.g. ISA deployment, ISA Manager can quickly spawn additional ISA via VPS Web Service API. The core function will be used to cone disk image from a virtual disk template library stored inside the resource pool. In the event that the current VPS resource pool has reached its limit, an ISA Manager can also copy the existing virtual disk template into a different resource pool that can be from a different VPS provider to commence cloning more ISAs to meet new demand without having to purchase additional hardware. There is no operational data stored inside the ISA, the runtime data is erased after every execution cycle.
3.5.3 Mobile Virtual Appliance (MVA)

Smartphones and tablet devices enable a new, rich user experience in pervasive computing. They are equipped with Internet access, GPS, digital cameras, motion sensors and applications coupled with a powerful mobile operating system such as Google’s Android, Apple iOS and Microsoft Windows 8 which are more powerful than desktop computers from a few years ago. Application developers can easily create device specific applications using Software Development Kit (SDK) with preinstalled Application Program Interface (API) library to access the sensors that are managed from the device’s operating system within the smartphone.

Mobile Virtual Appliance (MVA) extends the concept of Mobile Cloud Computing (MCC). Instead of depending on the device’s operating system to perform high-level, intensive computation tasks such as image or video processing, the raw data is uploaded to the cloud services and the process data is then posted back to the smartphone device. Battery power consumption is also reduced as the result of minimising the utilisation of the smartphone device’s local resources, especially the CPU. Therefore, the device can have longer operating time between charges.

Similarly, input from sensors built-in smartphone devices can be referenced via cross compiler API, the data obtained from the sensors can be posted directly to the cloud services. Since the data from the devices is processed externally at cloud services level, the application and process mapping can be altered and managed without having to update the mobile application on the physical device, thus, reducing the cost of managing the mobile application throughout its life cycle.

3.6 Implementation of VPS in Frosster

Frosster is a dairy distributor. The company that operates over 20 refrigerated trucks, delivering perishable dairy product such as milk, cream, cheese and butter for the National Foods brands products to local restaurants, cafés and convenient stores via refrigerated cross-docking facility to located in north of Melbourne, Australia. Since demand for perishable dairy products can alter within hours from the initial orders and as part of a strategy to improve customer service and increase sales volume, Frosster introduced a policy
to enable customers to add, update and remove product lines from their orders, 30 minutes prior to the vehicle’s departure from the cross-docking facility. Furthermore, the customer can also order additional items from the truck inventory safety stock, while the driver is unloading their orders.

In order to correctly capture the actual sales records, in 2002, Frosster had invested in Datalogic Black Jet, a ruggedize Microsoft Windows based PDA with barcode scanner coupled with Citizen Bluetooth mobile thermal printer at the cost of $3,000 and $1,000 per unit, respectively and at the cost of over $80,000.00 including software and implementation cost. The unit worked well initially for the first 2 years, however, as the rugged PDA started to wear, requiring battery, cables, charges and accessories to be replaced, it became very difficult to secure parts from existing supplier because the PDA had already gone out of production. Today, if a driver loses or damages the PDA beyond repair, it could take up to 6 weeks to reorder from Datalogic at a cost of $3,500 per unit and $1,200 for the Citizen mobile Bluetooth printer. The increase in costs of such old legacy device is due to holding costs incurred from manufacturers and distributors of mobile devices having to keep out dated, out of production device in inventory.

Today, the latest Android devices that are almost 10 times more powerful than the Datalogic Black Jet are selling for well under $200 per unit. However, because the current order capturing application was written for out-dated Microsoft Windows CE devices, it means that they are unable to replace existing rugged PDA devices with newer versions.

Microsoft ActiveSync is used to synchronise order data between the Datalogic Black Jet and the workstation using text file sync. The synchronisations are based on comparing timestamps between the workstation and the PDA, the latest revision of the files is then synchronised between the two devices. The mobile legacy application Hanzon will only work with ActiveSync based on Windows XP that will soon (April 2014) no longer be supported by Microsoft (http://www.microsoft.com/en-us/windows/endofsupport.aspx) . However, Hanzon inventory management system and database still operate with the current Windows Server 2008, operating system in 32bit mode.
A new adaptive cost effective solution is needed to enable both current Datalogic Black Jet device and newer cost effective devices that are not restricted to any operating system to function in parallel and interface directly with existing Hanzon inventory system.

3.6.1 Current Mobile Application Utilisation and Workflow at Frosster

With the existing order processing process (Figure 3.10), the customer service operator processes order requests from customers via telephone, fax and email. The requested orders are stored as preliminary sales, which are used as a guide the day shift cool room operators pick the order and preload the products into the refrigerated trucks, where the refrigeration units are kept connected to power sockets, to maintain cooling temperature. All the day shift operators finish at 17:00 and the phones are set on answering machine mode, where any amendment instruction to existing orders can be recorded as voicemail. When the drivers arrive at the depot later in the evening, they would check the voicemail and see if any of their customers had requested any change to their orders. If there are changes to the order, the driver would amend any changes via their PDA applications and print out a new pick slip to the cool room operator. The cool room operator would then remove excess stock or add additional stock, depending on the stock adjustment pick slip. Once the refrigerated truck is loaded, the driver would follow a set delivery sequences scheduled by the PDA application since all the deliveries are performed at night to avoid traffic congestion. Once the driver arrives at the destination, they can leave the order outside the customer’s front door or enter the customer’s premises with a key provided. On a typical night, depending on the size of the order, a driver would deliver between 40 to 60 deliveries. In some cases, the driver would deliver to 24 hours convenient stores, the customers would purchase additional items from the safety stock in truck inventory, which will need to be recoded using the PDA application. The customer can also return expired and damaged stock from previous orders back to the driver. It is critical that the driver correctly records any return stock, since it will be marked as credit on the customer invoice. Once the driver finishes his shift, the PDA is then handed back to the customer service operator, where the actual sales and credit data are synchronise to the Hanzon desktop application, where it is processed into customer invoices.
Figure 3.10 Current workflows in Frosster.

### 3.6.2 Mobile Virtual Appliance and Synchronisation Process

Both Datalogic Black Jet devices that are installed with the Hanzon mobile application will still be required to operate in parallel with the proposed mobile virtualisation framework. An additional interface is required to enable communication between the Hanzon inventory management system and the virtualisation framework resulting in the creation of an online web ordering feature for both desktop and mobile websites. These interactive features enable customers to add, update and delete products from their orders by a set cut-off time that conforms to the business rules. The same web interface is also used for internal telephone, fax and email orders. These ensure that all order data is populated with the same conformance in the virtualisation framework.

Once the current time exceeds the order cut-off time, the customer can no longer create an order with the same date, thus, they can only create orders as of the next available date. A scheduled import procedure is executed once the cut-off time is reach. The import procedure only imports data where Datalogic Black Jet and Hanzon mobile applications are utilised. It enables output files from the web interface to be generated to the Hanzon desktop application. The generated output files are then automatically imported into Hanzon’s preliminary sales record. Each PDA device is exclusively assigned to a route and each route
is exclusively assigned to a customer, thus, eliminating the scenarios where two or more types of PDAs are utilise by the same delivery driver.

The day-time cool room operator would pick for each route using a mobile picking WEBAPP (web application), similar to those found in scan-packing. The new PDA that utilises WEBAPP can synchronise the order route and truck inventory in real-time using the PDA local wireless or mobile network. Therefore, if utilised completely, it would eliminate the role of a customer service operator having to manually synchronise each PDA using a USB cable. As the night shift delivery driver retrieves the voice mail to amend their order details, any changes made will automatically update the picking task of the cool room picking WEBAPP, thus, eliminating the driver having to print out another picking slip for the night shift cool room operator.

As the night shift delivery driver begins to deliver his orders, the status of the order can also be relayed back to the virtualise framework in real-time. This is extremely useful for night operation managers to keep track of the status and activity of the entire fleet in real-time. Since the data, including actual sales transaction on the PDA are synchronised to the virtual framework in real-time, this eliminates the tasks of the customer service operator having to resynchronise the PDA prior to invoicing.

Figure 3.11 shows the new virtualisation frameworks implementation with native mobile application built using PhoneGap that is operating in parallel with existing Hanzon inventory management and legacy mobile application.
3.6.3 Lesson learnt from Frosster’s case

The comparison for both Virtualised and Physical can clearly be seen in Table 3.1. This clearly demonstrates that even with a small scale operations like Frosster, the cost of operating PDA data collection device can be very costly to maintain. Once the technology has been implemented, it is often very difficult for any business to amend changes to their existing process. When technologies, such as PDA and portable thermal printers are introduced to the business, the value of the initial investments are realised immediately, however, this is often foreshadowed by the ongoing costs of the maintenance. As the technologies begin to depreciate, additional resources and process change will need to be introduced to ensure the existence and continuity of the business process.

In the case of Frosster, the PDA and paperless technologies were implemented ahead of its time, and despite PhoneGap ability to deploy application to many devices, including Microsoft Windows Mobile, they only support Windows Mobile 7 and above, hence the current Datalogic PDA will not be compatible to the proposed PhoneGap mobile virtualisation framework. Thus, the decision to maintain both systems in parallel until such time that all Datalogic Black Jet PDAs are decommissioned.
<table>
<thead>
<tr>
<th>Tasks Details</th>
<th>ActiveSync and legacy mobile application</th>
<th>Virtualisation model with PGB and CAS.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application Update &amp; Patches</strong></td>
<td>Manually synchronise, for each individual device</td>
<td>Automatically deploy to CAS using PGB cloud services.</td>
</tr>
</tbody>
</table>
| **Number of times required to be synchronised manually** | 1. Preliminary sales  
2. Update truck inventory, by drivers  
3. Confirmation of actual sales | None, since all route are synchronise via Wi-Fi or mobile data network. |
| **Orders cut-off time**             | 16:30 or 30 minutes before the end of day shift to allow time to manually synchronise, to each individual device | 20:30 or 5 minutes before the night shift cool room operator update truck inventory. |
| **Costs of maintaining SDK and IDE to the developer** | Unpredictable, based on time billing and complexity of the SDK. ActiveSync may have conflict issue that are created by Windows Software Update Services (SUS), in which an IT administrator may need to be involve | Predictable, all SDK and deployment tools. PGB is free for 1 private APP or $9.99 per month for 25 private APPS. |
| **Estimate time saving per device per day** | Not Applicable | 18 minutes per device per day:  
1. Preliminary sales [3 mins]  
2. Truck inventory [10 mins]  
3. Confirmation of actual sales [5 mins] |
| **Estimate cost saving per device per day** | $10 per device per day, based on current wages | $10 per device per day, based on current wages |
| **Cost per replacing device**       | $3,200 each for Datalogic PDA  
$1,200 each for Bluetooth printer | Under $200 each |

Table 3.1 Comparison between cloud based and ActiveSync synchronisation.
3.7 Chapter Summary

The investigation in Frosster’s case reveals the advantage of virtualised infrastructure using virtual devices. The utilisation of universal languages such as HTML5, CSS4 and JavaScript to create native mobile applications via universal mobile compiler has been demonstrated. The ability to access smartphone device peripherals and apply basic logic using HTML5 syntax means that mobile application developers can quickly develop a universal application that is compatible with current and future smartphones and mobile devices. With the aid of PGB cloud services, mobile application developers can deploy their applications to other device APP stores without having to maintaining up-to-date SDKs and libraries. Scan pack application built using cloud compiler such as PGB can become more adaptive and compatible with different device profiles from various manufacturers.

By enhancing the virtualisation model with mobile platforms, supply chain hardware including barcode reader and RFID scanner can be emulated within the virtual mobile infrastructure, thus, improving the connectivity and transparency when smaller supply chain firms participate within the global supply chain. The increase in transparency from smaller supply chain firms will ultimately enable them to become more competitive with larger supply chain firms, therefore, providing a leaner and productive link to the global supply chain.

From the case study, it is clear that mobile application built using universal language coupled with XaaS service, such as VPS, can substantially reduce implementation and overhead costs in establishing mobile data capturing operations. Furthermore, the new structure is flexible to operate in parallel with existing legacy mobile data capturing platforms.

The utilisation of ISA at Gaffney Logistics eliminated repetitive manual data synchronisation tasks between isolated legacy systems. Virtualisation and hardware consolidation are critical factors for any ISA deployments. Time sensitive tasks can be achieved by executing the ISA in parallel. Since ISA performance depends on the internet speed which reflect the interface speed of the remote legacy system, it is preferably to house ISA using XaaS service such as VPS. With VPS, ISA can be deployed into a resource pool and re-deployed to other VPS resources with the aid of API bindings quickly.
Chapter 4 Event driven with Geo-fence

4.1 Introduction

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 et al., 1998). In most FMS applications, users can specify a location address which is then converted into GPS coordinate, geo-fence can then be created from the user by defining a radius parameter around the centre of the coordinate as shown in Figure 4.1. The GPS coordinates are transmitted at set time intervals from the personal digital assistant (PDA) or in-car modem with in-built GPS receiver which is mounted inside the vehicle. Data integrity is maintained even if the vehicle is in an area where mobile reception is not available, the coordinates and timestamps are stored inside the PDA, until such time that mobile reception is re-established (Chiang et al., 2008).

![Figure 4.1 Screen shot of TMS with embedded geo-fence.](image)
There have been many studies conducted on tracking materials inside warehouse facilities (Martínez-Sala et al., 2009). Section 2.4 discussed how GPS data is underutilised in transportation by supply chain firms which use historical data to generate KPI reports for customers, resolve billing issue and audit driver working hours. Wang et al. (2007) proposed an adaptive framework that incorporates geo-fence to trigger a series of datasets to emulate delivery notifications. The paper discusses GPS data that was not associated to the manifest data in TMS. Moreover, the trigger was activated whenever the GPS receiver appears inside a defined geo-fence. However, such assumption is incorrect in the real-world environment, because the GPS receiver can appear inside a geo-fence at different moments in time. Thus, the GPS receiver will need to be associated to the manifest data in TMS.

This chapter examines a GPS collaboration model that interfaces with TMS to accurately update and confirm manifest delivery status. The information can then be shared with CRM and WMS to accurately update EPC-IS databases where RFID infrastructures are not available.

4.2 Issues of work flow in transportation logistics

Many logistics companies incorporate GPS solutions as part of their Fleet Management Solution (FMS). The main purpose of a FMS is to provide real-time visibility to the company fleet, service schedule and utilisation reports to manage Occupation Health and Safety (OHS) so that drivers are not over worked. In many cases, with incidents such as theft or road accidents, GPS and vehicle telemetry are used as evidence to assist insurance claim.

In most cases, data traverses in a single direction where the TMS acts as a hub between the FMS and other applications such as WMS and CRM (refer to section 2.2). If a customer raises a query from the CRM “How far away is my freight?” the operators and/or system integrators would use the TMS to look up the consignment number (which is often refer to as tracking number), that is then used to reference the vehicle identification number delivering the consignments. The vehicle identification number is then passed through the FMS as a parameter and the latest value of the GPS coordinates, speed, headings, altitude and other telemetry are returned to the FMS.
The CRM manages queries for both TMS and WMS functions, while the manifest (refer to as Package class, see Figure 4.7) in TMS enables WMS SSCC data to also be embedded, as well as freight data. In most cases, especially in interstate and wharf cartage, it is inefficient to complete a delivery with one single trip. For interstate transport operations, smaller vehicles are often used to pick up freight and deliver it to a depot. The freight is then consolidated into a semi-trailer, which travels between interstate depots. Once the freight is off-loaded to the destination depot, it is then delivered to the final destination via smaller agile vehicles. This is reflected in the consignment class which store the pickup and the final delivery addresses. The Job class in Figure 4.7 is utilised to capture job details, including pickup-to-depot, depot-to-depot and depot-to-destination. Thus, the job class enables the transport operation to record the driver, vehicle and trailers utilised per trip (see Figure 4.2). In many cases, freight is routed between multiple depots to further improve efficiency. RFID could be utilised to provide a highly efficient track and trace function for interstate transport operations, however, it is heavily dependent on IT infrastructure that is expensive to setup and maintain. Apart of the additional cost of the RFID tags, it would restrict ad hoc consumers, who do not have RFID reader/writer from utilising the system.

![Figure 4.2 Workflow of interstate transport operation.](image)

In Figure 4.3, each freight pickups are treated as individual consignment instances. When delivering to large infrastructure construction projects, it is not always possible to deliver an order with a single consignment. This explains why there is a many-to-many relationship for Package and Job class in Figure 4.7. If an order requires many partial deliveries, it is important that WMS can query TMS to determine which products and quantity had been delivered onsite. Summarily, it is impossible to assume that every line picked can be packed into a single package. The LinePickedGroup class is utilised to track what products and
quantity are assigned to each package. In order to maintain the status and traceability of a partial order delivery, status variables will be required for Package and LinePicked classes (Figure 4.2).

![Diagram](image)

**Figure 4.3 Relationship between Order, Packages (freight) and Job classes**

Many wharf cartage operators choose to transport their container to and from the wharf at night to avoid traffic congestion and delay at the wharf during daytime. In many cases, this is done using a shuttle service known as bulk-run between the wharf and the depot (Figure 4.4). Export containers are also synchronised and scheduled as part of the bulk-run from the container yard to the wharf, so the vehicle and trailers are utilised to their maximum efficiency.

![Table](image)

**Figure 4.4 Bulk-run container movements**
A driver with a B-double trailer can transport up to three 20ft containers or one 20ft and one 40ft container per bulk-run. In one shift, a driver can perform as much as 8 or more bulk-runs. At the end of the shift, the driver would send a container arrival report to the fleet operator informing them what containers had arrived at the depot, so that it can be arranged for delivery to their customers. Even though the bulk-runs are a series of predefined container movements between the wharf and container depot, in many cases, as the import containers are about leave the wharf, they can be redirected randomly to an Australian Quarantine and Inspection Services (AQIS) inspection depot for X-Ray and Tailgate inspection (Figure 4.5). Thus, each container will need to be verified to ensure that it had arrived at the container yard before it can be scheduled for delivery to the customer warehouse or freight station via CRM requests.

Figure 4.5 Material flow of wharf cartage operation

It is possible for an integrated FMS-TMS solution to automatically generate container arrival reports by utilising geo-fence to trigger the pickup and arrival confirmation. Current TMS and FMS solutions are inter-linked so that TMS and query FMS data for a particular job to generate reports, however, that integration is one way. FMS systems are not associated to jobs inside TMS, thus, apart from providing up to date GPS positions, track and trace
function, they do not have any association with respect to time and space of each individual bulk-run.

All Point of Interests (POI) and pre-defined geo-fences are also stored as one layer inside FMS, and despite the ability to group geo-fence together as a variable within FMS; it is not practical to associate geo-fence group or layer to customer profile because there can be many geo-fences that exist closely and sometimes overlap to each other. These often occur when different customers utilise the same warehouse provider but label it as their own warehouse. Despite FMS ability to correctly locate GPS devices, it does not have the ability or visibility to reference jobs within the TMS.

Since all the bulk-run jobs are pre-allocated to a particular driver, vehicle and trailer that are mapped to registered GPS devices, with the current system, the first occurrence when the GPS devices enter a geo-fence, such as the wharf area, will automatically confirm all pre-allocated pickup for all bulk-runs in that shift (Figure 4.4). Similarly, when the GPS device first enters the depot, the current FMS system would automatically confirm that all the containers that have been pre-allocated are delivered to the depot. Thus, the container arrival report generated from current FMS and TMS integration would be inaccurate and useless.

Since all current integrated warehouse and transport solutions only support forward traversal, any delivery and package confirmation need to be manually triggered from the TMS operator or from PDA device at the time of delivery. As mentioned previously, it is not feasible to assume that PDA devices will always be readily available to all operators in the supply chain, therefore, new workflow between FMS to TMS and WMS that limit the visibility of the active job based on current time is required.

Figure 4.6 shows the bulk run pre-allocation based on data from Figure 4.4. Since conventional FMS and TMS interface do not reference the job with respect to current time, it will automatically trigger a pickup status for all jobs in Bulk-Run 2, when Bulk-Run 1 is triggered.
Automatic trigger all pre-allocate bulk-run based on first occurrence

Figure 4.6 Demonstration of “system presents” for bulk-run operation.

4.3 Modelling by UML

In order to understand the system and develop a new geo-fence model, Object Oriented Approach (OOA) is used. Interface data access classes (also known as wrappers) are introduced to each key application components (Figure 4.7). These classes include data access functions (getters and setters) and handling procedures that are combined into packages so that it can be reused and incorporated into API. The components are explained in the following subsections.
Figure 4.7 UML class diagram of an integrated WMS and TMS solution.

4.3.1 FMS GPS Interface

The key function for FMS wrapper class is to provide data access to the GPS devices and their location. The GpsDevice class provides access to specific GPS devices within the FMS. It also contains the latest instance of the GpsPosition class. The GpsPosition class contains data obtained from the GPS reader such as timestamp, latitude, longitude, headings, velocity
and altitude. Using \textit{gpsDeviceID} as a foreign key, GPSPositions can be search by various GPS reader variables to provide traceability to GpsDevice.

\textbf{4.3.2 TMS Interface}

TMS wrapper class is to provide a relationship between Packages class that is associated to a Consignment class with manifests (sometime refer to as legs), in a Job class. Since each Job class represents an individual trip within a Consignment class, there can be many Job class to a single Consignment class, which is common for interstate or wharf cartage operations. Within the Job class, there are instances of Vehicle and Trailer class, both classes will have a foreign key \textit{gpsDeviceID} that is associated to FMS API. The Package class within TMS can operate as standalone or with SSCC from WMS embedded. The variable \textit{packageTypeID} in Package class is used to trigger WMS lookup features or simply tread the package as standalone inside TMS class. Since there can be many packages associated to a single consignment, it is simply unrealistic to assume that all the packages can be delivered in one trip. Hence, to further improve the accuracy, the \textit{packageStatusID}’s are directly associated to each Job class, as there can be many trips, performed by various drivers, vehicles, and trailers to deliver all the packages to the same destination.

\textbf{4.3.3 WMS Interface}

WMS wrapper class is to encapsulate orders information that is invoked by WMS. The Order class in WMS is associated to both Consignment and Job classes in TMS. The Line class, contains the net quantity of the \textit{productID} which is associated to the product catalogue within the WMS. Since there can be many packages associated to a line item, at the same time, there can be many line items that are kept in the same package. Therefore, \textit{LinePicked} and \textit{LinePickedGroup} classes are utilised, with many-to-many relationship between the Line class and Package class of TMS. \textit{LinePicked} and \textit{LinePickedGroup} classes enable the WMS visibility and traceability of what items are stored in which package, similar to those of SSCC.
4.3.4 CRM GPS Interface

CRM wrapper class is used to handle and manage track and trace procedure invoked by CRM or WS. The `eventID` is a primary key used in the CRM wrapper class to track the status of each track and trace request. In general, the CRM will not have direct database access such as ODBC to both WMS and TMS, therefore, it is impossible to assume that all requests would return a result. If either remote WMS or TMS are offline, then the CRM wrapper will not be able to return a result. In many cases, in which an email trigger is requested upon delivery (this is commonly used in DHL, FedEx, and UPS), the execution of the track and trace does not actually happen until sometime after the delivery is completed.

4.4 System Design

In order to correctly invoke TMS job and consignment status from GPS data received from FMS, time condition and device state must be included as part of the parameters for the invocation. Instead of trying to synchronise the address book details inside TMS with geo-fence layer in FMS, the geo-fence data will be embedded to the TMS address book class so that it can easily be referenced. The real-time GPS data from FMS will be processed directly via a Web Service Application (WSA) that listens to dataset from both FMS and TMS. The key advantage of utilising web service is to enable flexible support for either legacy, MVA and cloud based solutions. In the example shown in Figure 4.1, Google map web service is used to perform a reverse lookup of longitude and latitude for a given address when ‘Find address on map’ button is pressed, at the same time, Google map is also used to render map overlays for the TMS.

4.4.1 Device State

Job details including address book and reference GPS device from TMS are passed through the WSA. At the same time, raw GPS data from the FMS are also being posted to the same WSA. Instead of trying to detect and compare the entire address book in the TMS, WSA only compare existing real-time GPS data with pickup and delivery address one at the time showed in Figure 4.8, thus, multiple job threads can be synchronised within WSA.
Figure 4.8 Flow chart of the WSA process

In many large distribution centres, including wharf, freight station and empty container parks, trucks can be queued up for many kilometres. It is common for the yard manager to redirect vehicles via service roads so that they can be loaded from scheduled time windows, referred to as time-slots. To avoid WSA from misinterpreting the device status (Table 4.1), WSA would examine a set of previous GPS records to ensure that the device is either inside the geo-fence, arrived at the geo-fence, departed the geo-fence and exited the geo-fence. The number of previous records that the WSA examines is dependent on the speed and size of the vehicle, GPS data transmission interval and the current state of the GPS device. For example, if the GPS data transmission was set to an interval of one minute per transmission while the GPS device is outside the geo-fence. If the GPS device is inside the geo-fence, the GPS data transmission interval could be lowered to 20 seconds per transmission to further increase response time and improve timing accuracy.
<table>
<thead>
<tr>
<th>ID</th>
<th>Device Status Description</th>
<th>Pre-Conditions</th>
<th>Post-Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>In transit, waiting to enter pre-define geo-fence zone</td>
<td>1. Driver and Vehicle allocate to consignment 2. <strong>Device Current Time (CT)</strong> within allowable time-window (e.g. +/- 1 hour) from Estimated Time of Arrival (ETA).</td>
<td>1. <strong>DeviceStatusID</strong> = 2 (Enter defined geo-fence)</td>
</tr>
<tr>
<td>2</td>
<td>Entering pre-defined geo-fence</td>
<td>1. <strong>Monitor last 10 known positions</strong> 2. If tracking velocity equals zero and the last 10 known positions are the same. It is then assumed that the vehicle has arrived at destination and/or has arrived into the docking station ready to be unloaded.</td>
<td>1. Check that current time is still within a valid time-window, else raise an time-mismatch exception to the operators 2. <strong>DeviceStatusID</strong> = 3 (Arriving at destination)</td>
</tr>
<tr>
<td>3</td>
<td>Arriving at destination</td>
<td>1. <strong>Start detention timer (DT).</strong> 2. <strong>Store Arrival Time (AT)</strong> 3. <strong>Each increment the GPS position is received, update DT where, DT=CT-AT</strong> 4. <strong>If DT = Allowable DT – 15 minutes, then send email to customer to alert that detention charges will commence.</strong></td>
<td>1. If velocity &gt; 0 and/or current position is not equal to previous. Then the vehicle has finished unloading. 2. Check if current position is outside the define geo-fence. If so, set <strong>DeviceStatusID</strong> = 4 (Departing destination)</td>
</tr>
</tbody>
</table>

Table 4.1 GPS device status and event detection for wharf cartage operation.
4.4.2 Time conditions

In order to avoid pre-mature arrival and delivery confirmation, time conditions are used in order to restrict the job schedule from being monitored by the WSA. The `pickupTimeMargin` and `deliveryTimeMargin` variables inside Action class (Figure 4.7) enable the operator to arm the scheduled jobs within defined time windows. In Figure 4.4, container KKTU7710270 is expected to be delivered to the wharf at 23:00. Utilising a web-service such as Google Map, the WSA estimated trip time between the container yard and the wharf. For example, assuming the trip time is 30 minutes, the required pickup at the container yard is 22:30.

*Pickup 22:30@Container Yard -> Delivery 23:00@Wharf,*

If the operator allow 15 minutes for pickup time margin and 30 minutes for delivery time margin, then

*Pickup 22:15-22:45@Container Yard -> Delivery 22:30-23:30@Wharf,*

Note that the pickup and delivery time can overlap; therefore, multiple points can be armed at the same time.

4.4.3 Job Status

To ensure that correct job sequences (Table 4.2) are maintained in WSA, `jobStatusID` variable, in Job class, (Figure 4.7) are used to track current job status.
<table>
<thead>
<tr>
<th>JobStatusID</th>
<th>Job Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Generated from TMS</td>
</tr>
<tr>
<td>1</td>
<td>Confirm required pickup and delivery time.</td>
</tr>
<tr>
<td>2</td>
<td>Assigned driver, vehicle and trailer.</td>
</tr>
<tr>
<td>3*</td>
<td>Picked up</td>
</tr>
<tr>
<td>4*</td>
<td>Delivered</td>
</tr>
<tr>
<td>5</td>
<td>Closed</td>
</tr>
<tr>
<td>6</td>
<td>Invoiced</td>
</tr>
</tbody>
</table>

*Job triggered automatically using WSA

Table 4.2 Job status description

For WSA to automatically update job status in TMS, it will need to follow the sequence set in Table 4.2 and device state in Table 4.1. Therefore, WSA cannot update job status to deliver (4*) before it is picked up (3*), regardless that both pickup and delivery times are within valid time windows (armed). This feature is extremely useful when pickup and delivery locations are in very close proximity of each other.

4.4.4 Consignment Status

WSA can use the jobs delivered status as an aggregator to trigger other supply chain functions. In the import bulk-run scenario, a job delivered status would be used to alter the consignment status to “at container yard, ready to be scheduled for delivery to customer warehouse”, alternatively for export bulk-run, would alter the consignment status to “at wharf, finished export procedure, ready to invoice”. Similarly, the job delivered status can also be used to trigger packages and order status as described in Figure 4.3.

4.5 Implementation at Action Transport Logistics

A wharf cartage operation was selected to demonstrate the effectiveness of geo-fence with time conditional model. A “system present” interpreter was also developed to create and route GPS receiver event to an in-house TMS system code name TRANSACTION. The GPS data was obtained using a free GPS tracking service called InstaMapper (http://www.instamapper.com) and GPS Tracker smartphone application. The result of this
geo-fence with time condition are also discussed in extensively in “Extended system design for RFID enabled supply chains with non–RFID technologies“ (Mo et al., 2012) and “RFID implementation with virtual infrastructures” (Lorchirachoonkul et al., 2010)

4.5.1 Capturing GPS Data with Smartphone

InstaMapper is free GPS (Global Position System) tracking software for iPhone, Blackberry and Android smartphones with built in GPS. Using mobile internet technologies, InstaMapper automatically uploads the current GPS location of a mobile device to InstaMapper database. Users can then log on the InstaMapper website and track their previous positions. Due to the limited storage available by InstaMapper (100,000 positions per devices) registered database replication technique was used to append the data to FMS local database. By creating an account with InstaMapper, users are provided with API keys that enable GPS data from smartphones to be retrieved using Web Services.

4.5.2 Defining Geo-Fence

Google MAP API was used as the mapping interface. Since there are thousands of physical addresses inside the TMS database, it would be extremely time consuming for the fleet operator to manually locate and define each geo-fence. In order to speed up the lookup process geocoder.getLatLng() was used to obtain each address Latitude and Longitude (Figure 4.1). Where the physical freight handling area is different to the actual site address, the marker can also be moved using drag-and-drop interface, so that the geo-fence can be accurately mapped.

4.5.3 Monitoring GPS Data

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 with a valid time condition, an arrival timestamp is stored inside the FMS. An event can be triggered that leads to a set of predefined tasks being put to action, such as an update on the job status, at the same time, it can also start up another
monitoring procedure to automatically alert a customer if additional detention charge will commence, hence, reducing billing enquires down the track. As the vehicle is unloaded and leaves the virtual geo-fence, the departure timestamp can be stored and vehicle loading time calculated.

Figure 4.9 Vehicle tracking using GPS in TMS

4.5.4 Detecting valid Geo-Fence

The logic of detection has further complication. In Figure 4.10, the virtual gate is represented as a circular boundary that overlaps a small section of a major highway. The vehicle will need to pass through this to gain access to the pickup or delivery address. In order to validate that a vehicle is in fact on the actual delivery point and not just passing by, the system will need to check that the last $n$ positions (where $n$ is a set number, normally greater than 5) are all within the defined geo-fence in a present time condition. The shape
of the virtual gate can vary depending on the requirements. Using a defined polygon, a better result can be achieved, but the geo-fence will be more complicated to define.

Figure 4.10: Circular geo-fence and in-fence detection process

4.5.5 Raising Run-Time Event

The concept is to emulate RFID readers as part of a virtualised infrastructure that integrates RFID and non-RFID devices into a global track and trace system. The geo-fence allows emulated RFID data to be used at locations where installation of the RFID infrastructure is not possible. In Figure 4.11, 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.

Figure 4.11: Geo-fence data integrated with ERP

4.6 Chapter Summary

In this chapter, the development of geo-fence and WSA to collaborate various supply chain applications was discussed. WSA provides a two way process synchronisation between WMS, TMS and FMS. The geo-fence triggers events that can be used as an aggregator to streamline supply chain relationship between various parties. For example, freight forwarders can be notified and forwarded any detention charges in real-time to their clients. Currently, detention charges are sent to the freight forwarder manually via emails from the carrier or they are received with the final invoice from the wharf cartage carrier. Disputes
between freight forwarders and cartage carrier often result in a series of additional administrative tasks for both parties to resolve. Since most cartage carriers utilise factoring facilities, the financial institutions involved may need to adjust and audit their retention to reflect any credit made to the freight forwarder by the cartage carrier. A real-time autonomous solution would reduce detention queries or disputes between freight forwarders and cartage carriers.

By utilising time constrained algorithm with real-time data analyser, accurate and meaningful events can correctly be recognised. Thus, enabling the WSA to generate events obtained from GPS positions stored inside FMS. Furthermore, the events created from WSA can also be integrated with other physical system, such as EPCglobal and other RFID networks. The virtual event created from WSA can be used to provide track and trace information to ECP-IS RFID network, where RFID infrastructures are not currently present.
Chapter 5 Network Resource Management Model

5.1 Introduction

Obtaining reliable internet end-point is a critical factor for successful global supply chain deployments. Using Anycast to manage route internet traffic to the nearest geographical location may not be practical in supply chain due to security concerns raised in section 2.5. In conventional EPC architecture, the EPC-IS are often stored behind each companies firewall, thus, it is as only reliable as the internet end point.

This chapter explores two methods of optimising cloud services and end-points connection within the RFID realm. The first method is to introduce multi-hosted services Sub-Cloud Services (SCS) which route services depending on the location of the end-points via managed DNS lookup and clustering. The second method uses Queued Compression, to optimise the communication of physical devices and cloud services by reducing the network overhead. These methods are developed to solve communication between hosted service and devices that are subjected to low quality network coverage.

5.2 Background of Fosstrak EPC-IS database

Fosstrak (fosstrak.googlecode.com) is an open source and is an EPCglobal-certified EPC-IS Repository as well as Query and Capture clients, written in Java. There are two main components in Fosstrack interface (Figure 5.1).

1. The capture interface utilise XML text object that are conform to EPC-IS XML event type schema (Figure 5.2).

2. The query interface that utilise SOAP/HTTP binding (Figure 5.3). The query can be executed as a schedule event or triggered event, where the result can be aggregate to a difference EPC-IS Repository.
Rui et al. (2012) discussed the design and development of a traceability service for EPC based Food Supply Chains and utilises Fosstrack as part of the simulation. However, the results obtained are based upon local network, which may not reflect real-world conditions. The query interface in Fosstrack assumed that the aggregate query server will always be available with reasonably good connectivity. These assumptions cannot always be applied in global supply chain environments, since we cannot assume that all EPCIS repositories will be connected to a reliable fixed IP address.

Any aggregate EPC-IS host will be heavily dependent on their end-point. The performance of the overall system is closely matched to those hosted by the ISP, (Anderson et al., 2005).
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<epcis:EPCISDocument
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:epcis="urn:epcglobal:epcis:xsd:1"
    xmlns:epcglobal="urn:epcglobal:xsd:1"
    xsi:schemaLocation="urn:epcglobal:epcis:xsd:1 EPCglobal-epcis-1_0.xsd"
>
    <creationDate>2008-03-16T22:13:16.397+01:00</creationDate>
    <schemaVersion>1.0</schemaVersion>

    <EPCISBody>
        <EventList>
            <ObjectEvent>
                <eventTime>2008-03-16T22:13:16.397+01:00</eventTime>
                <eventTimeZoneOffset>+01:00</eventTimeZoneOffset>
                <epcList>
                    <epc>urn:epc:id:sgtin:0614141.107346.2017</epc>
                </epcList>
                <action>OBSERVE</action>
                <disposition>urn:epcglobal:epcis:disp:fmcg:unknown</disposition>
                <readPoint>
                    <id>urn:epc:id:sgln:0614141.07346.1234</id>
                </readPoint>
                <bizLocation>
                </bizLocation>
                <bizTransactionList>
                    <bizTransaction type="urn:epcglobal:fmcg:btt:po">
                        http://transaction.acme.com/po/12345678
                    </bizTransaction>
                </bizTransactionList>
            </ObjectEvent>
        </EventList>
    </EPCISBody>
</epcis:EPCISDocument>

Figure 5.2 Example of EPC-IS ObjectEvent, serialised into XML. Source (fosstrak.googlecode.com)

<epcisq:Poll xmlns:epcisq="urn:epcglobal:epcis-query:xsd:1">
    <queryName>SimpleEventQuery</queryName>
    <params>
        <param>
            <name>eventType</name>
            <value>ObjectEvent</value>
        </param>
        <param>
            <name>MATCH_epc</name>
            <value>urn:epc:id:sgtin:0614141.107346.2017</value>
        </param>
    </params>
</epcisq:Poll>

Figure 5.3 A sample query asking for ObjectEvents having an EPC equal to urn:epc:id:sgtin:1.1.0. Source (fosstrak.googlecode.com)
Large amounts of EPC XML can be generated from a single RFID reader, due to the reader ability to read multiple tags at the same time. Large amounts of data will need to travel through HTTP via TCP/IP protocol, which may not be possible for a low bandwidth network such as GPRS / 3G connection.

5.3 Sub-Cloud

In a global supply chain management, different organisations from around the world will need to access the same set of information concurrently; therefore, if the data was hosted in a single location then the QoS can be varied dramatically depending on geographical location of the hosted site. This is particularly concerning when real-time transaction data are being transmitted directly from physical devices such as RFID readers with a low quality internet connection.

5.3.1 Theory of pipe-peering

Many CaaS utilise Pipe-Peering Connection (PPC) to reduce jitter and packet. PPC is a private dedicated connection to the ISP back-bone. Instead of utilising Quality of Service (QoS) at each endpoint to route high priority data packet, such as VoIP across the internet, data packets pass-through directly between CaaS and the end users using PPC, via ISP backbone, thus, improving the efficiency and the quality of the real-time data packet transmission.

In Australia, VoIP provider FakatorTel (www.faktortel.com.au) utilised PPC. From our testing, the ping time from our PBX using PPC is 25-40ms, compared to a non PPC provider PennyTel (www.pennytel.com.au) with a ping time of 150-180ms. However, the benefit of PPC can only be realised with the support of multiple ISPs, which are not always willing to participate. Furthermore, the costs associated in establishing and maintain PPC from each well-known ISP, can be extremely expensive.
5.3.2 Implementation of Sub-Cloud

Within the internet cloud are series of routers which connect each access point to their destination. Typically, if the servers and the access points are geographically close to each other, there would be less routing between sites when compared to servers that are placed geographically further away. Thus, the requirement for high speed low jitter networks is one of the critical requirements in order to implement a real-time system, such as RFID, especially if using Cloud Computing technologies were utilised.

The key requirements for ‘sub-cloud’ include:

1. Reduce the volume of data required to be routed between each physical endpoints.
2. Increase the reliability of each service layer, by utilising data replication and publication across a multi-hosted solutions.
3. Ability to repackage so that it can then be used with other enterprise models.

For most Small to Medium Enterprises (SMEs) web based applications or SaaS are commonly hosted from a single location. This is usually from a dedicated data centre or a secure robust office environment. In general, applications would communicate from a server to the clients via series of routers connected between different ISPs. As the geographical distance between server and the client increases, so do the expected increase in the number of routes between ISPs, hence increasing the connection time.

(Lorchirachoonkul et al., 2010) discussed the design of an enterprise bus code name "Transparent", for managing and collaborating different RFID systems for a global supply chain enterprises. Lorchirachoonkul and Mo also discuss the utilisation of a mobile device such as an Apple's iPhone as a physical host for virtual RFID readers, where Quick Response (QR) Code are used in conjunction with RFID tags.

It would be very inefficient if both virtual and physical RFID readers only interact with a single hosted cloud service. Both virtual and physical devices can also take different routes to access the cloud service especially if the devices are in different countries/regions to the hosted site. Therefore, internet cloud should not be viewed as a single cloud but as several
small segments of sub-cloud that are joined together by different routes to create an internet cloud network.

In order to improve the performance of the cloud service across the global supply chain, sub-cloud services will need to be deployed across various major ISPs around the world. When a registered device wants to access the cloud service, an IP lookup is performed to determine the location of the client, then a list of nearby servers are nominated. From the ping and jitter results, it is possible to determine which of the nominated servers are best suited to connect to the registered device. The information obtained from the registered device is then replicated to the adjacent hosts to provide additional redundancy and improve clustered performance (Figure 5.4).

Figure 5.4 Multi-hosted sub-cloud services (SCS) providing additional redundancy and improved performance.
5.4 Challenges with legacy RFID infrastructure

Mo et al. (2009) demonstrated the implementation of RFID using EPCglobal network across multiple enterprises. The Nation EPC Demonstrator Project (NDP) allows different organisations with defined roles to interact with each other in a secure and transparent manner, using Electronic Product Code (EPC) Network. However, some of the key issues identified in the NDP were ensuring that each organisation that interacts with NDP had conformed network and IT infrastructure in place. Since each organisation choose to store their local Object Name Server (ONS) and their Electronic Product Code Information System (EPC-IS) Server behind their firewall, in order to validate critical transaction, such as change of ownership, the NDP Portal need to query multiple EPC-IS servers that are hosted behind each organisation's firewall. Therefore, the integrity of the supply chain transaction heavily depends on the availability of the EPC-IS servers that are individually maintained by each organisation (Figure 5.5).

An EPC network will query multiple EPC-IS databases that are stored behind each organizations’ firewalls (Wamba et al., 2006). The assumption by most researchers is that all connections are always active. However, in the real-world, it is very difficult for an organization to keep its network running all the time, let alone ensuring that all related supply chain networks are also operating. Furthermore, each organisation could also face issues that are outside their control, such as link failure at their internet service provider (ISP) or physical failure at their end-point, which could ultimately reduce the overall reliability and availability to their supply chain network. If one of the links is broken due to system response, connectivity, security or other reasons, that request may not be executed and if the result of that particular query is required to trigger an event or change of ownership, it could potentially lead to query timeout, dead-lock or possible data corruption.
Currently, many network devices and IT infrastructure can be emulated and then consolidated in a physical host. The virtual devices have the same characteristic and are identical to the physical devices but shared the resources of a physical host. Therefore, network appliances and servers can be consolidated into a physical host. The resources of the physical host are then managed by a hypervisor which acts as a central resource manager for all emulated virtual devices. Virtual devices are stored as an image file within the hypervisor, therefore, it can easily be backed up with preset configuration and can be deployed as multiple instance. Thus, organisation within the NDP could easily adopt virtualisation techniques to improve the scalability and utilisation of their existing networks and IT Infrastructure as RFID systems evolved.

Cloud computing allows complex applications to be hosted within the internet cloud. Thus, complex RFID network infrastructure, such as the EPCglobal demonstrated in the NDP can then be remodelled with virtualisation and cloud computing technique to provide greater
scalability, reliability and affordability when compared to standalone physical infrastructure shown by the NDP (Figure 5.2).

Since the applications are hosted within the internet cloud, the reliability and the performance of the supply chain networks are improved, because access to critical data, such as EPC-IS are queried directly from the internet cloud, instead of behind an access point protected by firewalls that are managed individually. However, this would also mean that the physical RFID readers will also need to communicate directly with the SaaS across the internet cloud. If there are multiple readers collecting large amount of data from a single site, a reliable internet link, with a high upload speed will be a critical component for cloud computing implementation of EPCglobal.

However, high speed internet link is not always possible to acquire, especially in newly developed industrial estates. In many cases, newly developed warehouses will often rely on GPRS and 3G wireless connection as their primary source of internet. To further improve the performance of the wireless network throughput in remote locations, some supply chain organisations utilise network load balance (NBL) technique, in which multiple Universal Serial Bus (USB) GPRS/3G/4G wireless adaptors, from various network operators are used to increase bandwidth and network performance in shared environments(Peng et al., 2008; Wenbin et al., 2009). Wireless router manufacturer such as Cradle Point (http://www.cradlepoint.com) manufactured routers which have built-in wireless access points for multiple USB wireless interfaces. It also has a built-in QoS function to optimize the local network traffic. Since the resources of multiple network providers are used, it is very difficult to establish a reliable static public IP address, which is paramount for existing RFID network, such as EPC Network as demonstrated by the NDP.
5.5 Experimental Verification in Thailand

In May 2010, several shopping centres and distribution centres in Bangkok, Thailand were set on fire by Thais protesters (http://www.theage.com.au/world/bangkok-rioting-huge-shopping-mall-faces-collapse-20100519-vf6z.html). As part of a disaster recovery plan, temporary distribution centres were set up outside the city centre, however, access to high speed broadband was not available. Thus, GPRS/3G/4G wireless networks were used as a primary internet link until the fire damaged distribution centres can be rebuild.

5.5.1 Background

To investigate the method of maintaining low bandwidth throughput in real-time network environments, two network quality tests were conducted in Bangkok, Thailand from a temporary local distribution outlet, where two wireless median were used. A single local 3G and EDGE wireless USB interface were used to in our test shown in Table 5.1 and Table 5.2 respectively. Further tests also found that the connection can fluctuate by up to 40% during peak period.

Network Quality test using GPRS / EDGE network was conducted in Bangkok, Thailand. The ISP used TOT Public Company Limited and i-Mobile 3G SIM with 60% reception. The test was conducted, using www.speedtest.net and www.pingtest.net during non-peak period, i-Kool 3G SIM which also terminated at TOT was also utilized, with similar results to TOT. Packet lost occurred when a transmission of data packets failed to reach the destination. This is mainly due to connection drop out or timeout. Any packet lost is unacceptable in any real-time system.

Ping reports the duration for a data packet to travel from the source (local computer) to destination (server) then back to the source. The value of 100ms should be expected from a reasonable broadband connection. Jitter is the variance in measuring successive ping duration. Thus, the lower the jitters value is recorded, the better the broadband connection is. It is common to experience jitter over the internet, however, it should be a small fraction of the ping result for a reasonable broadband connection.
<table>
<thead>
<tr>
<th>Country / Provence</th>
<th>Ping (ms)</th>
<th>Jitter (ms)</th>
<th>Down (Mb/s)</th>
<th>Upload (Mb/s)</th>
<th>PKT Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia/ Canberra</td>
<td>454</td>
<td>24</td>
<td>0.37</td>
<td>0.55</td>
<td>3%</td>
</tr>
<tr>
<td>New Zealand/Christchurch</td>
<td>261</td>
<td>22</td>
<td>0.89</td>
<td>0.85</td>
<td>2%</td>
</tr>
<tr>
<td>China/Xiamen</td>
<td>567</td>
<td>149</td>
<td>0.47</td>
<td>0.28</td>
<td>4%</td>
</tr>
<tr>
<td>Taiwan/Taichung</td>
<td>330</td>
<td>67</td>
<td>0.51</td>
<td>0.08</td>
<td>2%</td>
</tr>
<tr>
<td>India/Mumbai</td>
<td>400</td>
<td>17</td>
<td>0.39</td>
<td>0.30</td>
<td>4%</td>
</tr>
<tr>
<td>Pakistan/Karachi</td>
<td>722</td>
<td>288</td>
<td>0.87</td>
<td>0.29</td>
<td>1%</td>
</tr>
<tr>
<td>United Kingdom/ Manchester</td>
<td>400</td>
<td>11</td>
<td>0.57</td>
<td>0.21</td>
<td>2%</td>
</tr>
<tr>
<td>Spain/ Madrid</td>
<td>401</td>
<td>18</td>
<td>0.59</td>
<td>0.33</td>
<td>3%</td>
</tr>
<tr>
<td>USA, Miami, Florida</td>
<td>337</td>
<td>12</td>
<td>0.86</td>
<td>0.17</td>
<td>0%</td>
</tr>
<tr>
<td>USA, San Francisco, CA</td>
<td>282</td>
<td>13</td>
<td>0.75</td>
<td>0.28</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 5.1 Network Quality test with 3G network, the test was conducted in Bangkok, Thailand in 2010.

<table>
<thead>
<tr>
<th>Country / Provence</th>
<th>Ping (ms)</th>
<th>Jitter (ms)</th>
<th>Down (Mb/s)</th>
<th>Upload (Mb/s)</th>
<th>PKT Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia/ Canberra</td>
<td>543</td>
<td>86</td>
<td>0.13</td>
<td>0.05</td>
<td>0%</td>
</tr>
<tr>
<td>New Zealand/Christchurch</td>
<td>584</td>
<td>90</td>
<td>0.14</td>
<td>0.04</td>
<td>0%</td>
</tr>
<tr>
<td>China/Xiamen</td>
<td>418</td>
<td>35</td>
<td>0.18</td>
<td>0.07</td>
<td>0%</td>
</tr>
<tr>
<td>Taiwan/Taichung</td>
<td>636</td>
<td>36</td>
<td>0.17</td>
<td>0.07</td>
<td>1%</td>
</tr>
<tr>
<td>India/Mumbai</td>
<td>375</td>
<td>37</td>
<td>0.14</td>
<td>0.07</td>
<td>0%</td>
</tr>
<tr>
<td>Pakistan/Karachi</td>
<td>585</td>
<td>50</td>
<td>0.16</td>
<td>0.06</td>
<td>0%</td>
</tr>
<tr>
<td>United Kingdom/ Manchester</td>
<td>702</td>
<td>114</td>
<td>0.12</td>
<td>0.07</td>
<td>0%</td>
</tr>
<tr>
<td>Spain/ Madrid</td>
<td>646</td>
<td>64</td>
<td>0.11</td>
<td>0.08</td>
<td>0%</td>
</tr>
<tr>
<td>USA, Miami, Florida</td>
<td>575</td>
<td>59</td>
<td>0.16</td>
<td>0.05</td>
<td>0%</td>
</tr>
<tr>
<td>USA, San Francisco, CA</td>
<td>620</td>
<td>64</td>
<td>0.16</td>
<td>0.05</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 5.2 Network Quality test with GPRS network, the test was conducted in Bangkok, Thailand in 2010.

At the time of the experiment in 2010, 3G is only available in the metropolitan area of Bangkok and therefore, cannot be the benchmark condition used to implement our solution. GPRS / EDGE provided most of coverage in Thailand. Since most of the local distribution role is to send back RFID scanned tags information, attention to the upload speed is more
critical than download speed. From Tables 5.1 and 5.2, the upload speeds for both 3G and GPRS / EDGE network are on average 40% slower than the download speeds and do not provide adequate levels of ping and jitter delays to justify for real-time system implementation. This demonstrated that current mobile data connections are not reliable or stable enough for real-time systems such as RFID. In order to reduce TCP overhead, a new transmission process needs to be established for low quality mobile data connection.

5.5.2 Queue Burst Data Compression (QBDC) Model

When utilising a high quality internet connection, the ping speed between server and access point is relatively fast. However, with a wireless connection, such as GRPS/3G/4G, the connections to the access points are terminated with additional wireless interface which have higher overhead than a wired DSL connection. Thus, data rate heavily depends on the reception quality between the mobile towers and the wireless access point.

From the result obtained in section 5.4, when using GPRS as access point, the average upload speed is 0.05 Mb/s, which is inadequate for uploading large amount of data in real-time environment. Therefore, improvement to the performance and efficiency of the communication between end-points and the cloud services were required.

A process called "Queued Burst Device Compression" (QBDC) has been used in this experiment. QBDC is a transport communication process that provides data compression between access points and sub-cloud services. Nearly all RFID readers send back EPC tag information as a text string, which are highly compressible when converted into a text file. The RFID readers redirect the EPC tag information to a QBDC application which stores the tags information into memory. At a defined burst interval, the QBDC application then writes the tags information as a text file, where it is automatically compressed and then dispatched to the cloud service. Since the compression ratio, for most open source libraries (such as 7-ZIP http://www.7-zip.org), is approximately 10 times those of the uncompressed data, it is in fact faster to queue the data and then transmit at a burst interval than to send raw data directly from the RFID reader. Furthermore, the communications of ObjectEvents are transmitted using XML which is extremely inefficient when compared to JSON (JavaScript Object Notation) (Rodrigues et al., 2011). Thus, the ObjectEvents can be converted from
XML to JSON before applying the compression filter to further reduce the amount of data transmitting to the hosted EPC-IS (Figure 5.6).

Figure 5.6 Data compression using QBDC

Products are often received in palletise packaging to and from distribution centres. RFID tag readers are often placed in loading dock doors to confirm the arrival of the products. Due to the confined space of the trailer, which are usually two pallets wide, the maximum speed that a pallet can travel via a loading dock using a forklift is approximately 10-15 seconds per pallet. In a scan pack operation, only single RFID tags are used, and the serial shipping container code (SSCC) is encoded to the RFID tags. SSCC are used to describe "What is in the box?", between trading partners across the supply chain. However, there could be scenarios in which operations are required to tag the inside of SSCC content. These are usually small high valued items, which specific serial numbers are also read and verified. In such case, it is possible for several RFID tags (possibly a few hundreds or thousands) to be read in a single pass. This would then put pressure on the end point connection to the cloud service, especially if the upload speed is poor. If the rate of the data stream exceeds the upload bandwidth, then any transmitted data will have to remain in the RFID reader's memory before it can be uploaded to the cloud. Ultimately, if the rate of data being read is greater than the upload bandwidth, the RFID reader will eventually run out of volatile
memory and fail. QBDC can help prevent such failure by dequeuing the data in each RFID readers at each endpoint and then compressing the data stream in real-time before transmitting to the cloud services. Input stream from RFID tags are transmitted to the middleware as text stream, using basic zip encoding, the compression ratio is approximately 10:1 (see Table 5.3) which means for a 0.5 Mb/s GPRS connection, utilising QBDC will have a net yield of 5 Mb/s. Since the QBDC transmitted the compressed data stream in a burst sequence, network contention ratio are also improved, due to reduced network overhead from managing individual packets directly from each RFID readers. The details of sub-cloud and QDBC research have been published “Design of RFID cloud services in a low bandwidth network environment” (Mo et al., 2011)

<table>
<thead>
<tr>
<th>Country/Provenience</th>
<th>Un-compressed [12.16Mb] (sec)</th>
<th>JSON [6.08Mb] (sec)</th>
<th>QDBC [0.118Mb] (sec)</th>
<th>QDBC JSON [0.032Mb] (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia/Canberra</td>
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<td>14.56</td>
<td>2.29</td>
<td>2.01</td>
</tr>
<tr>
<td>New Zealand/Christchurch</td>
<td>15.85</td>
<td>9.32</td>
<td>1.91</td>
<td>1.69</td>
</tr>
<tr>
<td>China/Xiamen</td>
<td>48.49</td>
<td>31.25</td>
<td>5.21</td>
<td>4.78</td>
</tr>
<tr>
<td>Taiwan/Taichung</td>
<td>161.72</td>
<td>98.52</td>
<td>12.78</td>
<td>8.45</td>
</tr>
<tr>
<td>India/Mumbai</td>
<td>43.58</td>
<td>24.75</td>
<td>4.23</td>
<td>3.67</td>
</tr>
<tr>
<td>Pakistan/Karachi</td>
<td>45.93</td>
<td>26.84</td>
<td>4.31</td>
<td>3.86</td>
</tr>
<tr>
<td>United Kingdom/Manchester</td>
<td>61.58</td>
<td>34.59</td>
<td>5.98</td>
<td>4.87</td>
</tr>
<tr>
<td>Spain/Madrid</td>
<td>43.55</td>
<td>27.41</td>
<td>2.56</td>
<td>2.33</td>
</tr>
<tr>
<td>USA, Miami, Florida</td>
<td>78.52</td>
<td>42.55</td>
<td>6.91</td>
<td>5.89</td>
</tr>
<tr>
<td>USA, San Francisco, CA</td>
<td>48.58</td>
<td>31.55</td>
<td>5.49</td>
<td>5.14</td>
</tr>
</tbody>
</table>

Table 5.3 Benchmark QDBC based on 1000 simulated events with 3G connection, the test was conducted in Bangkok.

5.6 Chapter Conclusion

This chapter discusses in detail the challenges in deployment and maintenance of an RFID integrated system such as NDP. Experience has shown that it would be almost impossible to define and maintain a level of network services that are privately maintained by each organisation within the supply chain.
Utilising Virtualisation and Cloud Computing to remodel RFID provide a scalable, reliable and affordable implementation of RFID system, but a high quality internet connection is required at each end point to facilitate such implementation. Unfortunately, high quality internet links that are suitable for real-time system such as RFID are not always available, and in many case GPRS/3G wireless connection is the only source of internet connection, especially in newly developed industrial estates. Two different solutions were proposed that will enhance the performance of the cloud computing implementation of RFID systems, such as EPCglobal. First, Sub-Cloud Service (SCS) is based on a multi-hosted cluster environment, which each access point are automatically routed to the nearest sub-cloud host, based on geographical as well as ping and jitter results. Using data replication between adjacent hosts further improves reliability and performance of each EPC-IS instances across the supply chain enterprise realm. Queued Burst Device Compression (QBDC) model can provide real-time compression for low quality link such as GPRS/3G wireless connection, which QBDC stores information obtained from RFID readers in a queue, then compress and send it at define interval, reducing TCP overhead. The compressed data is then decompressed and processed at the cloud hosts. This process reduces the network overhead suffered when transmitting in small segments of transaction data across low quality internet links. Since the two solutions are independent of each other, they can be implemented separately or consecutively so that their effect can be cumulated to maximise the efficiency of the network.
Chapter 6 Global Logistics Integration Framework

6.1. Introduction

Global supply chain management (SCM) is largely built around scan pack logistics, where information is exchanged between trading partners using EDI (van Antwerpen, 1992). Order information is transferred via point to point and product codes and barcode catalogues must match between trading partners. Since the exchange of data is point to point, product catalogue do not always conform to standards such as EAN. However, in a global supply chain, each trading partner is often required to deal with other trading partners, vendors and 3rd party service providers (3PL), each with their own systems, processes and standards.

The process of picking orders from multiple customers, managing and resupplying inventory from multiple suppliers are critical supply chain functions, referred to as Scan Pack Logistics. As discussed in section 2.2.2 there are various implementation standards that exist in current global supply chain including EPC, NPC, and UID. EDI messaging and point to point (P2P) communication is the core communication model used in scan pack logistics operation. However, P2P limits the ability for seamless collaboration of information within a supply chain, which is one of the key motivations for the development of the global logistics integration framework.

This chapter combines the foundation from previous chapters in virtualisation, cloud computing, network management control and virtual appliance into a useable class that can be referenced and indexed by API therefore, providing concurrent connectivity between virtual and physical networks across multiple standards.

6.2. Background

Today, companies use Enterprise Resources Planning (ERP) systems extensively for managing the manufacturing and delivery processes (Viswanadham, 2000). Typically global supply chain operation is initialised when an overseas manufacturer receives a purchase order (PO) from the client ERP. Once the products are packed, the information is sent to a central RFID repository where the information such as location or status of a particular tag is updated in real-time. An international forwarding agent is then notified and makes necessary arrangements to ship the freight order to its correct destination. Tag information
from the central RFID repository can also be accessed by customs broker for clearance purposes. Once the goods arrive, they are unpacked. Since each package is already assigned a specified distribution centre or retailer outlet, the products are cross-dock, instead of receipting into inventory. The scenario throws some ideas into consideration. First, since companies from several countries are involved, future RFID enabled virtual enterprises should possess easy entries and exits as much as possible. In essence, the issue is that of flexibility. Enterprise systems should adopt generic standards that are compatible with noncomplying organisations, for example, customs and retailers. Second, the routes for physical goods movement are predominantly one way, that is, from manufacturer to the retail outlet. However, it has been observed that RFID tags are not 100% reliable. The virtual enterprise system should have a contingency plan to deal with nonperforming tags and goods return. Thus, to enable business activities of the future business scenario, the decision system should expand and a corresponding development of the information system is also expected. After the expansion, the new functions are:

- **Rules**: explicitly govern the operations of a supply chain, e.g. acknowledgement procedure, case level bundling, non-perfect reads, pick face, re-read alert, wrapping

- **Inventory management**: keeps track of how goods are encountered and registered, e.g. smart shelf, stock replenishment levels, storage and retrieval procedures

- **Operations**: required the enterprises to prepare for managing activities, e.g. delivery schedule, layout planning, transportation timetable, human resources planning. An enterprise model can be refined to incorporate additional layers of functions as decision centres. Since the EPC Network forms the basic backbone of the EPC enterprise information system and “business” layer identified while analysing the impact of NDP Extension. The next phase is to modify the enterprise model with increased business and enterprise layers as shown in Figure 6.1.
In Figure 6.1, the model shows that significant enhancement must be developed in the decision system to handle issues in supply chain management and operations. This can be done by further refining the dotted objects to finer levels with responsibilities of the stated tasks assigned to individual departments and work groups. The model also shows extension of the information system beyond the EPC Network structure to cater for the need of the decision system. By reference to the national projects, the lower parts of the decision system are currently available. For more generalised use, this part of the architecture has to be standardized so that it can be made plug and play in any business environment. For physical layer processes, equipment for interacting with actual goods movement is normally vendor specific and can be upgraded readily. The movement of goods are drawn below the physical layer function but are controlled by decision centres. In the physical system, there are
configuration problems that need to be resolved. The design principle is detect-and-read but
the physical system design is largely experimental. With strict standardization compliance,
most existing hardware vendors are able to provide devices with this capability.

6.3 The Global Logistics Integration Framework

The Global Logistics Integration Framework (GLIF) is a multitier graph that collaborates
data sent from SCM services providers which are then indexed by different standards in a
global repository, known as global registers. Each global register is used to keep track of
identifier standard instances such as registered data collection devices, product items
identification, package items containers and warehouse locations. The global registers are
reflecting the functionality of the layer 3 and 4 functionality of the EPC system (Figure 6.3).

![Figure 6.3 Level diagram GLIF Architecture.](image)

Since there are many standards that exist today (Schmitt et al., 2008), an output from a
device can be interpreted in many ways depending on the data content read from the device
and the role of the assigned device. For example, a GPS receiver inside a vehicle can be
modelled as physical GPS reader, at the same time it can also be used as a data source to
monitor if the GPS receiver is inside a target geo-fence. Therefore, the output from a
physical device can also be used as a component of a virtual device. The coordination of
interpreting data source from various services and data sources from device sensors are known in GLIF as Event Management.

6.3.1 Global Register

The global registers are used to keep track of multi-systems objects in the supply chain. It is necessary to note that objects may exist in multiple instances amongst different systems and platforms.

![Figure 6.4 Global Register with Event Bindings](image)

**6.3.1.1 Global Device Register (GDR):**

Global Device Register (GDR): Used to maintain instances of physical device, such as smart phones and GPS devices. Each GDR are given a unique identifier. They are constantly being monitored against other GDRs and GLRs. Events are raised if a GDR meets a predefined condition, e.g. when a GDR enters into a predefined geo-fence at a specific time.
6.3.1.2 Global Item Register (GIR):

Global Item Register is used to identify items with multiple encoding standards. Each item is given a unique GIR number. This will enable GLIF to uniquely identify items that may have different encoding but refer to the same product. In Chapter 7, GIR are also used in UGI to store each item’s physical property as a point cloud and binary image so that it can be detected with both a 2D and 3D camera using computer vision.

6.3.1.3 Global Location Register (GLR):

Global Location Register is used to identify multiple locations that could reside within the same geo-fence. Each location, such as warehouse location is given a unique GLR number. This will enable GLIF to uniquely identify a location's address rather than just depending on the geo-fence alone. This is very useful when delivering into an office building, where the same geo-fence is shared with many addresses.

6.3.1.4 Global Package Register (GPR):

Global Package Register key function is to track and manage packages within the GLIF realm. This includes logistics units, which can travel between trading partners and internal branches. Manufacturers, importer, distributors and direct customers can extract detailed tracking information, even if the logistics unit was managed by multiple 3PL providers.

6.3.1.5 GLIF Device Connector (GLIF-DC)

GLIF Device Connectors (GLIF-DC) are used to interface between each organisation’s end points and GLIF. Since GLIF can support many event handling types that are not exclusive to EPCglobal standard, it can also be used with other standards as well as peer-to-peer connection. In order to reduce network overhead, GLIF-DC can also be implemented on local network server to manage multiple GLIF-DC devices. GLIF-DC can also incorporate OBDC discussed in Chapter 5 to further reduce network overhead for mobile devices with low-bandwidth. In the event where GLIF-DC has loss connectivity to GLIF, the data
collected from GLIF-DC are temporary stored inside the device’s memory until such time that communication to GLIF can be established.

Figure 6.5 Screen shot Transparent Connector for mobile device.

6.3.1.6 Event Bindings

Event Bindings are used in GLIF to generate events by monitoring the interaction between GIRs. Using GLIF-DC is use to transmit data from different sensors, the event binding class is used to check if the condition of the global register has been met. For example, a GPS sensor (GDR) is inside the parameter of a particular geo-fence (GLR). The routing option in the event binding class enables other dependent events to be executed after the initial detection.

6.3.1.7 Event Management

Event Manager in GLIF provides data collaboration between physical and virtual sensors. It is responsible for managing all pre and post-procedures defined in the service model class that control the event execution and data translation function to physical networks (Figure 6.6). Furthermore, event manager will also need to synchronise data between legacy systems and Event Binding class. In order to reduce complexity between interfaces to legacy systems, ISAs are automatically built in as part of the service model class.
6.4 Integration with mobile devices

For warehouse and entry portal applications, a digital camera similar to the quality of a webcam can be used to capture the tag. The information can be encoded by the computer for onward passing to on-site EPC-IS. Alternatively, if the application requires mobility, mobile devices with in-built cameras can be configured to be registered to GRD with GLIF-DC to scan QR code enabled items. Since QR code is essentially a picture on canvas, the scanning process for QR code can be done on almost any device with a digital camera and can be easily operated by any warehouse staff. The GLIF-DC will then decode the information immediately and manage the event handling using the GLIF event binding class. In a supply chain environment, information such as product code, serial number and production date can also be encoded using 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 are 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 GIR to limit the size of the QR Code to improve scanning performance. GIR information can also be retrieved when it is passed in as an URL parameter.

6.4.1 Interface with geo-fence

GPS devices are dump devices that can only receive GPS signals for information of the driver. In order to return GPS coordinates to the FMS, a PDA with GPS capability is configured to transmit location information at set time intervals (e.g. every 2 minutes). 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. The event binding class can filter out any invalid signal and feed useful information to an event manager, which can trigger a pre-defined process set in the service model class.

In Figure 6.7, demonstrate the utilisation of Event Bindings and the Service Model class. The event binding constantly monitors the GDR with respect to the GLR geo-fence. In this example, if the GDR is inside the defined GLR geo-fence parameters, the service model thread is then executed. Each service model thread can be executed mutually exclusive to each other, thus, it can be used to monitor the vehicle stationary time inside the geo-fence zone. If the loading time exceeds that allowed in the customer’s service level agreement (SLA), additional charges can be added and the billing system is triggered. At the same time, the service model thread could trigger an arrival event to EPCglobal in XML format, using GLIF built-in translator.
Figure 6.7 Event binding monitor data from GDR against geo-fence defined in GLR

It is noted that the actual arrival timestamp will be the time that the system detects that the vehicle enters the “geo-fence” zone. This is dependent on the size of the “geo-fence” (i.e. the logical radius or shape of zone polygon) and GPS update interval. Therefore, it will never be as accurate as if the tag were scanned physically by a reader. However, it is very cost effective to have the geo-fence as a virtual gate, since the only capital cost involved will be the GPS on PDA which is now a standard tool in most logistics operation.
6.4.2 Interface with existing asset

Figure 6.8 demonstrates how the extended model is implemented for different companies interacting with GLIF. Each organisation operates their own proprietary enterprise resource planning (ERP) solutions which are hidden away behind their firewall. Using GLIF-DC, the supply chain partners establish a connection to the GLIF which exchanges information between various RFID networks and interfaces. Companies A and B are established trading partners and are members of the EPC network. Company C is Company A’s outsourced logistics provider and does not have any RFID infrastructure. Company C’s primary role is to facilitate pick and transport service on behalf of Company A. This service is triggered by Company B’s pre-order advice (POA) to Company A. Since Company C is not a member of the EPCglobal network, any activities handled by Company C will not be visible to Company A and B. Thus, the performance of the supply chain is heavily degraded, especially in a Just-in-time (JIT) operation, where lead time and inventory records are critical.
6.4.3 Collaboration of Systems and Networks

GLIF-DC synchronises the activities of physical EPCglobal network from company A and B. At the same time, GLIF synchronises events generated from company C’s virtual EPC network back to the physical EPC network of companies A and B. It is also important to note that company C may also service orders for other company A’s customers that are not members of EPC network or belong to other RFID network as long as those customers are a part of GLIF subset where they may not have GLIF Connector installed, but exist in the Global Location Register (GLR). Event generated from GLR will still be visible to company A via GLIF, thus, improving the visibility and traceability of the overall supply chain between all parties.
The GLIF has been tested in a local logistics company managing movement of containers between ports and warehouses. The customer, who is a manufacturer of canned and processed food located at an offshore facility, uploads their bill of lading (BOL) into GLIF to initialise the ordering process and the registers. The order details are then routed by GLIF into the local logistics company database, in which a link to the FMS is made. The FMS constantly monitors the voyage data published from the stevedore companies. Once the vessel arrives into the local ports, the logistics company then communicates with the stevedore and requests a timeslot to pick up the container. A driver, vehicle and trailer are allocated and the information is returned to the stevedore company for security verification.

At this point, the geo-fence is activated and communicates with the FMS to create a relationship between the manufacturer’s BOL and registered assets in GLIF. The system then waits for the respective GDRs to enter the specified geo-fence at certain time windows. When the condition is reached, the FMS sends a message back to GLIF updating the tracking status of the order, which is visible to everyone in the supply chain. Once the container arrives at the local depot, it is then unpacked, palletised and a QR code is attached to each pallet. An event is raised by a mobile server when a QR code is read by cameras at the dispatch area. GLIF is notified as the shipping container leaves the local port. Since the retailer is part of the RFID network that GLIF interfaces with, an advance shipping notification (ASN) message is sent to their enterprise system alerting them of arrival of the shipment. From this point onwards, GLIF takes control of goods tracking and communicates with the retailer’s RFID system when the consignments are finally delivered.

6.5. Implementation with Wharf Cartage operation

The Global Logistics Integration Framework (GLIF) theory has been implemented and utilised in commercial environments known as Transparent. (Lorchirachoonkul et al., 2011) and (Mo et al., 2012) discussed the design of a multi-layer enterprise bus code name “Transparent”, to collaborate information from various authorities and standard. Transparent then apply the concept of process emulation and visualisation, such as using geo-fence defined rules to trigger events that would normally require expensive and complex network and infrastructure. As well as providing a low cost based model, Transparent can also be applied to existing physical network for added redundancy. Since supply chain management...
are heavily dependent on rigid and stable IT infrastructure, in many cases, most collaborated information driven systems are simply turned off and supply chain operations revert back to a manual systems when a network or hardware failure occurs. Time critical data is then not being transmitted to the stakeholder on a timely manner, thus, creating failures and disruptions to the rest of the supply chain network.

Wharf cartage operations are an integral function of 3PL providers, also known as carriers. The carrier’s objective is to pick up a full container from the wharf, deliver it directly to the customer, and return the empty container back to the shipping line’s empty container park. This process is part of the import process. The same process is applied in reverse for export operation. Information from various shipping lines need to be collected and synchronised before a freight operator can make a judgement on when and where to collect a particular sea freight container. For this function to work, information about their container movements must be shared, and published across the supply chain network. Real-time information and planning of empty container movement must be made available to both external authorities including rival wharf cartage companies. With existing manual data collating process, this function is very tedious and leads to a lot of confusion. Recently, RFID has been considered for container applications with some level of success (Ngai et al., 2007). Since the containers can be tagged with RFID, the only information that needs to be ascertained after securing the container is to associate the RFID with a universal identifier within Transparent.

6.5.1 System Operation

To ensure that each vessel is loaded with as little delay as possible, export containers are received at the terminal before import containers are unloaded. Before a container can be collected or delivered to each terminal, a carrier need to request a time-slot (when and what containers are to be collected) from each terminal. Once the container has been unloaded, the carrier is then notified, within 48 hours to pick up the empty container and return to the designated empty container park. The carrier only has a limited time (usually eight days) since the first day of vessel availability to return the empty container (de-hired) back to the empty container park, otherwise, the carrier is penalised by the shipping line. Since each external authority operates their own legacy system, the 3PL providers will need separate security access for each external authority which will cause security and administrative
issues across the supply chain. A typical 3PL provider may have multiple logins with different authorities that shared similar information and perform generic functions within the supply chain (Langley, 2007). Since the information cannot be accurately obtained without cross referencing with another source, it is the responsibility of each 3PL to manually validate each data set manually. This process is extremely time consuming and prone to errors.

Figure 6.9 Management of empty container using GLIF

Figure 6.9 shows typical wharf cartage operations. A vehicle enters an empty container park when an empty container need to be returned to the shipping line for an import operation. For an export operation, a vehicle collects the empty container and delivers it to the client for packing. The full container is then delivered to the wharf ready for export. Import and export operations are isolated from each other. While an import vehicle is returning the empty container to the empty container park, an export vehicle can collect the empty container for export. For this reason, empty container park are always very congested. In order to increase productivity and vehicle utilisation, if an empty container park is
congested, the empty container is brought back to the 3PL container yard where it can later be de-hired when the empty container park is less congested.

Utilising Transparent, an empty container is returned to the 3PL company’s container yard, it is possible for the company to publish the details of the empty container details (shipping line, type, size, etc.) so that other 3PL companies nearby who need a container of same specifications for export operation, can coordinate the release of the container with the shipping line from a 3PL yard rather than the congested empty container park. The advantage is the 3PL performing the import operation automatically to de-hire the empty container without going to the empty container park. Meanwhile, the 3PL that performs the export operation can pick up the empty container without going to the congested empty container park, thus, improving the productivity and efficiency of physical container movement for both 3PL companies.

6.5.2 Cost Justification

The Transparent system was built from free open-source software. The system was implemented at Action Transport Logistics (Lorchirachoonkul et al., 2010). The company has operations in three states in Australia. This section provides a comparison of the cost savings that have been achieved by the virtualisation of RFID implementation. It is assumed that staff training requirements for operating the system will be identical.
Table 6.1 shows the costs for an EPC compliant system. The system consists of network routers and server installations as initial setup costs. The annual costs are computed on the basis of maintenance and network subscription.

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Unit Cost</th>
<th>Qty</th>
<th>Sub Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victoria - Altona Head Office</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFID reader per loading dock with 4 antennas</td>
<td>$4,500</td>
<td>6</td>
<td>$27,000</td>
<td></td>
</tr>
<tr>
<td>CISCO network components</td>
<td>$12,000</td>
<td>1</td>
<td>$12,000</td>
<td></td>
</tr>
<tr>
<td>HP DL380 G6 (EPC-IS, ONS Server)</td>
<td>$15,000</td>
<td>1</td>
<td>$15,000</td>
<td></td>
</tr>
<tr>
<td>Licenses, Installation, setup</td>
<td>$9,000</td>
<td>1</td>
<td>$9,000</td>
<td></td>
</tr>
<tr>
<td>Total initial setup cost Victoria Head Office</td>
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<td></td>
<td></td>
<td>$78,000</td>
</tr>
<tr>
<td>2 M/Bit frame relay</td>
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<td>$35,000</td>
<td></td>
</tr>
<tr>
<td>CISCO network maintenance</td>
<td>$990</td>
<td>1</td>
<td>$990</td>
<td></td>
</tr>
<tr>
<td>Annual cost Victoria Head Office</td>
<td></td>
<td></td>
<td></td>
<td>$35,990</td>
</tr>
<tr>
<td>New South Wales - Homebush Bay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFID reader per loading dock with 4 antennas</td>
<td>$4,500</td>
<td>4</td>
<td>$18,000</td>
<td></td>
</tr>
<tr>
<td>CISCO network components</td>
<td>$6,500</td>
<td>1</td>
<td>$6,500</td>
<td></td>
</tr>
<tr>
<td>HP ML350 G5 (ONS Server)</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td>Server Installation, setup fee</td>
<td>$200</td>
<td>10</td>
<td>$2,000</td>
<td></td>
</tr>
<tr>
<td>Total initial setup New South Wales Office</td>
<td></td>
<td></td>
<td></td>
<td>$36,500</td>
</tr>
<tr>
<td>1 M/Bit BDSL</td>
<td>$15,000</td>
<td>1</td>
<td>$15,000</td>
<td></td>
</tr>
<tr>
<td>CISCO network maintenance</td>
<td>$990</td>
<td>1</td>
<td>$990</td>
<td></td>
</tr>
<tr>
<td>Total annual cost New South Wales Office</td>
<td></td>
<td></td>
<td></td>
<td>$15,990</td>
</tr>
<tr>
<td>Tasmania – Devonport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFID reader per loading dock with 4 antennas</td>
<td>$4,500</td>
<td>2</td>
<td>$9,000</td>
<td></td>
</tr>
<tr>
<td>CISCO network components</td>
<td>$7,000</td>
<td>1</td>
<td>$7,000</td>
<td></td>
</tr>
<tr>
<td>HP ML350 G5 (ONS Server)</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td>Server Installation, setup fee</td>
<td>$250</td>
<td>10</td>
<td>$2,500</td>
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<td>Total initial setup Tasmania Office</td>
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<td></td>
<td></td>
<td>$28,500</td>
</tr>
<tr>
<td>1 M/Bit BDSL</td>
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<td></td>
</tr>
<tr>
<td>CISCO network maintenance</td>
<td>$990</td>
<td>1</td>
<td>$990</td>
<td></td>
</tr>
<tr>
<td>Total annual cost Tasmania Office</td>
<td></td>
<td></td>
<td></td>
<td>$40,990</td>
</tr>
</tbody>
</table>

Total initial setup cost $143,000
Total annual cost $92,970

Table 6.1 Implementation costs of EPC based infrastructure

The system includes RFID readers at all sites but there is still no guarantee on the accuracy of tracking when the goods are in transit between sites. To recover the return on investment, for the next four years, the company will need to generate an additional four million dollars in revenue per annum to justify such expenditure.
<table>
<thead>
<tr>
<th>Item Description</th>
<th>Unit Cost</th>
<th>Qty</th>
<th>Sub Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Victoria - Altona Head office</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RFID reader per loading dock with 4 antennas</td>
<td>$4,500</td>
<td>2</td>
<td>$9,000</td>
<td></td>
</tr>
<tr>
<td>CISCO network components</td>
<td>$4,000</td>
<td>1</td>
<td>$4,000</td>
<td></td>
</tr>
<tr>
<td>iPhone 3GS or Fix GPS transmitter</td>
<td>$1,100</td>
<td>40</td>
<td>$44,000</td>
<td></td>
</tr>
<tr>
<td>HP ML350 G6 (Transparent Connector)</td>
<td>$10,000</td>
<td>1</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td>Licenses, server installation, setup</td>
<td>$9,000</td>
<td>1</td>
<td>$9,000</td>
<td></td>
</tr>
<tr>
<td><strong>Initial setup subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td>$76,000</td>
</tr>
<tr>
<td>GSM/GPRS data plan (no contract)</td>
<td>$120</td>
<td>40</td>
<td>$4,800</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$2,500</td>
<td>1</td>
<td>$2,500</td>
<td></td>
</tr>
<tr>
<td>CISCO network maintenance</td>
<td>$990</td>
<td>1</td>
<td>$990</td>
<td></td>
</tr>
<tr>
<td><strong>Annual cost subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td>$8,290</td>
</tr>
<tr>
<td><strong>New South Wales and Tasmania Offices</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No installation and operation required</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Initial setup total</strong></td>
<td></td>
<td></td>
<td></td>
<td>$76,000</td>
</tr>
<tr>
<td><strong>Total annual cost</strong></td>
<td></td>
<td></td>
<td></td>
<td>$8,290</td>
</tr>
</tbody>
</table>

Table 6.2 Virtualised system with partial RFID capability at the head office.

Since inter-packaging only occurs at Victoria’s main distribution centre, physical RFID implementation is not required at other branches.

It is important to acknowledge that free open-source EPC-IS applications such as www.fosstrak.org exists. Open-source software has the advantage that tips for many difficult solutions can be found on development forum specially designed for particular software. Participants of the forum work with the original software developers in a truly collaborative fashion. Responsibility of continuous upgrading and future usage is shared among all participants of the forum, which mitigates a lot of risks in future development of the system.

For an EPC-IS to query other ONS servers, it need to have a relatively high quality link between the ONS sites. The major costs of setting up and maintaining the link, as well as the initial setup of the hardware (RFID readers, antennas, networking, cabling) were significantly reduced by virtualisation of functions within the infrastructure.
6.6. Conclusion

The GLIF has been created and consists of virtualisation and emulation of mobile devices. To prove that GLIF works, a supply chain integrated system under the code name “Transparent” has been developed in (Mo et al., 2012), which demonstrated how alternative technologies such as Quick Response Code (QR Code), Global Positioning System (GPS) and other peripherals within smart phones can be coupled with pre-defined business logics to emulate events triggered by physical RFID tags.

The result of implementing the Transparent Framework in the case study shows substantial benefits can be achieved by virtualising the RFID infrastructure to include non-RFID events and processing. As new mobile devices become available, more versatile systems and processes that allow new goods identification technologies to adapt to new cloud services is needed. The Transparent Framework has made use of many existing Internet services in its development. There is no guarantee that these services will continue indefinitely in the future, which could mean significant risks to the companies. The research in virtual infrastructures should therefore, not only focus on the development of specific functionality on available Internet services, but also diversify to establish a rich set of alternative services that can be used to replace functionality that suddenly disappear due to unknown reasons. GILF enables alternative cloud services to be utilised as alternatives that is readily available for operational backup. This objective is achievable with a large number of practitioners in the field and all contributing to the solution of common interest.
Chapter 7 Three dimensional gesture interpreter for retail operations

7.1 Introduction

The challenge of connectivity, compatibility and interoperability in global supply chains can be overcome with the utilisation of a Global Logistics Integration Framework (GLIF) (Figure 7.1). However, in today’s supply chain management, many of the existing scanning technologies are not feasible for retail point-of-sales (POS) operations. Despite the increased popularity of smartphone devices and advancement in self-checkout mobile applications (APPS), retailers are still heavily dependent on manual scanning products at checkout. Unlike other industry sectors in global supply chains, for an automatic checkout process to occur in the retail sector, a monitoring system is required that will capture what items the user has picked up and are placed in the basket. Since the retailers do not have direct control over their customers’ mobile devices including:

- Installed applications,
- Mobile device Connectivity,
- Mobile device Security,
- Mobile device condition and battery life.

Therefore, the retailer cannot totally rely on utilising the customer mobile devices for the automatic checkout process nor can they assume that the customer will even own or bring their mobile devices to store. Utilising RFID technologies in an automatic checkout system will require every item inside the retail store to be embedded with compliance RFID tags. Although RFID may not be a very practical or realistic approach to automatic checkout systems (discussed in section 2.8), nonetheless it is a view that is commonly shared between most researchers and industry practitioners.
Figure 7.1 Issue with device dependency for auto checkout in retail operation

In order for a system to be totally ubiquitous, it must be hidden from the user (Langheinrich, 2002). Since GLIF can provide product and location mapping resources at global level, the same theory can also be utilised at a local store level.

<table>
<thead>
<tr>
<th>GLIF Interface</th>
<th>Retail store mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Item Register (GIR)</td>
<td>Store Item / SKU (Stock Keeping Unit)</td>
</tr>
<tr>
<td>Global Location Register (GLR)</td>
<td>Location of store shelf</td>
</tr>
<tr>
<td>Global Package Register (GPR)</td>
<td>Store basket/trolley</td>
</tr>
</tbody>
</table>

Table 7.1 GLIF Mapping for automatic checkout system

In order to utilise GLIF as part of an automatic checkout system requires a transactional event to be triggered, which will enable the association between GIR and GPR (store item and basket). One method of generating such transactional event is to monitor shoppers’ instances inside the store. As a shopper places an item from the shelf into the basket, a transactional event is generated, resulting in the shift of inventory from GLR to GPR.
This chapter investigates a new automated check-out model that utilises an array of 3D cameras to detect users’ gestures combined with an array of high-resolution 2D cameras to further assist with the object detection that utilises GLIF to interpret and synchronised input from an array of optic sensors. Unlike traditional automatic checkout models that are largely based on RFID which the focus of the system is at the checkout detection zone, the proposed ubiquitous checkout model will also have the following characteristics:

- Identify and monitor each user as they enter the store
- Monitor the users’ movements within the store compound
- Track and identify items picked up by users
- Track and monitor the items in the basket
- Capture users’ interaction with other devices e.g. Electronic Scale
- Independent to mobile and other scanning devices
- Products do not require to be tagged using specific technology
- Conforms to GLIF standards

### 7.2 3 D Camera Technology

Three dimensional cameras are also known as Depth or RGB-D cameras operated by emitting thousands of infrared light beams from the camera viewport. The camera then captures the light beam as they bounce off the object in the room; the brighter the light, the closer the object is to the camera. However, if the object is too close to the camera, the light beam detected will be too bright, thus, there is a minimum distance that the camera will be able to operate. Therefore, each depth camera model will have a defined operating range usually between 0.8 to 3.5 meters.

Traditionally 3D cameras are expensive costing between $9,000 for Mesa Imaging Swiss Ranger SR4000 [http://www.mesa-imaging.ch/swissranger4000.php](http://www.mesa-imaging.ch/swissranger4000.php) and $12,000 for PMD Technologies [http://www.pmdtec.com/](http://www.pmdtec.com/) Cam Cube 2.0. In 2010, Microsoft introduced their Kinect 3D camera as part of their proprietary gaming console interface. Not long after launch, a hacker, Hector Martin created the first Linux open source driver for the Kinect 3D camera. The open source driver for the Kinect 3D camera enabled many types of application to be developed, especially in the area of robotics. At a retail price of $149, the Kinect 3D
camera offers good value when compared to other movement sensors of similar specifications. Realising the potential of Kinect 3D camera, Microsoft in 2012 released Kinect for Windows with API support for their Windows Platform (http://www.microsoft.com/en-us/kinectforwindows/). At the same time, manufacturers like ASUS had launched Xtion Pro Live RGB-D cameras to compete with Kinect cameras (http://www.asus.com/Multimedia/Xtion_PRO_LIVE/). Both Asus Xtion Pro Live and Microsoft Kinect cameras utilise the OpenNI framework (http://www.openni.org/).

Figure 7.1 shows the processing layer of 3D cameras with OpenNI and Natural Interface Technology for End-User (NiTE) computer vision middleware. The NiTE algorithms utilised raw data such as depth, colour, IR and audio received from OpenNI hardware devices, which enable the application to locate hand and joint tracking. Each joint coordinate (X, Y and Z) to be accurately determined with respect to the 3D camera’s position.

![Figure 7.2 Skeleton joints detection using 3D camera](image-url)
However, despite NiTE’s ability to capture 3D point cloud object and interpret into 3D skeleton joints (Figure 7.2), collaboration with additional sensors and data schema are required to accurately identify objects with the same physical attribute with different labels.

7.2.1 Tracking users’ movement

As the user moves from one camera view to another, the user’s “Head” joint positions are updated relative to the each camera’s viewport (X, Y, Z). Since each camera position is associated to GLIF’s GIR and GLR, UGI can then map the relative positions of each user and the product associated to camera view within the store. It is possible for a user to be detected with more than one camera, due to overlap viewing angles. In which case, UGI would nominate the camera with the minimum distance to the user’s “Head” joint.

UGI also tracks the moment of the user’s gesture joints [ShoulderLeft, ElbowLeft, WristLeft, HandLeft, ShoulderRight, ElbowRight, WristRight, HandRight]. If any of the user’s gesture joints enters the segmentation area, which is a space mapped within UGI, that gesture and object detection can be triggered. Each shelf contains a “Level number” and it is then mapped to the store product catalogue. Thus, based on the user’s hand coordinate with respect to the 3D camera store’s position, it is possible to identify which products are available for the user to pick up (see Figure 7.3).
7.2.3 Gesture Detection

In order to accurately identify that the user had picked an object up from the shelf, the hand joints are carefully monitored. The library like “SimpleHandTracking” from Tango Chen (http://kinecthandtracking.codeplex.com/) can determine if the user's hand is open or closed. If the user’s hand is closed and both of the user’s hand joints had departed from the shelf, UGI will assume that the user had picked up an item, and would begin to query GIR to detect the item picked. The picked gesture is then verified when the hand is re-opened after the user hand joint is lowered to drop the item into a trolley or basket (see Figure 7.4).
7.2.4 Object Detection

Using camera sensor array, the proposed Ubiquitous Gesture Interpreter (UGI) model will track the location of each shopper as they enter the store. Their skeleton joint movements will be detected using the NiTE computer vision middleware and Microsoft Kinect 3D camera SDK that enables the UGI to accurately monitor each shopper’s joint movements in a 3D space. A pickup gesture can be detected as the shopper's hand reaches into a store shelf that forms part of the detection area. Once a “pickup item” gesture is detected, the UGI then uses the images obtained from the high-resolution 2D cameras to further validate the item picked, using BLOB (Binary Large Object) library from Transparent Global Item Register (GIR) and cross referencing it with Global Location Register (GLR) mapping. In the event that the item picked-up by the shopper does not match the expected GIR library, GLR will perform the spanning search to see if the item belongs to the adjacent item (Figure 7.5). In the event where UGI could not recognise the item picked-up by the shopper, an alert maker will be place on the shopper which will alert the store operator to direct the shopper to proceed to manual checkout. In general, UGI will also track and monitor which item is currently in each shopper’s trolley or basket in real-time. As the user moves into a checkout zone, the UGI can then request electronic payment for the items in the shopper’s basket, without any physical scanning performed.
In order to identify which products are being picked off the shelf, point cloud can be used to detect object profile while BLOB catalogue is used to verify if the item that the user picked up corresponds to the item mapped to the shelf by the GIR (see Figure 7.6). The alternative method is to utilise a b-tree search and try to match the product of the adjacent shelf (in case the item picked was initially misplaced). It is important to note that in our prototype the current (Version 2.3.1) OpenCV SURF (Speed Up Robust Features) objects detection ([http://sourceforge.net/projects.opencvlibrary/](http://sourceforge.net/projects.opencvlibrary/)) can take up to 3 seconds to validate the object. For this reason, this validation can be performed on the fly as it will degrade the performance of the system. In the proposed UGI mode, Open CV object detection will only be activated if a pick event is triggered from the Kinect camera output.
7.2.5 Users Location

Initial investigations of multiple Microsoft Kinect 3D cameras are used to create a single viewpoint array. Multiple users can be tracked along the camera array and up to two skeletons can be tracked per Kinect camera (based on current SDK). Figure 7.7 demonstrates the layout of the Kinect camera array where each Kinect camera is positioned to track the skeleton joints of the user. As the user walks pass the entry, they can be identified using their membership ID. Another option is to detect the user using their skeleton’s profile and face detection. However, such option may not be feasible due to consumer privacy act (Garfinkel et al., 2005).

Once the users enter the detection zone (Figure 7.8), the UGI keeps track of a variable \( \text{Ucount} \) which represents the total number of skeletons within the detection zone. If \( \text{Ucount} \) exceeds the maximum allowable threshold of the Kinect camera array (2 users per Kinect Camera), an entry gantry will not allow the additional user to enter the detection zone once the threshold is reached.
Figure 7.7 The layout of the Kinect camera array mapping inside propose retail store.

Figure 7.8 Users in proposed retail store being detected with Kinect camera array.
7.3 GLIF Modelling of UGI

Using Object Oriented Approach (OOA), GLIF Global Register GDR, GLR, GPR and GIR classes are extended to handle the additional requirements. The UML diagram shown in Figure 7.9 defines the methods in which Global Register classes are extended. One of the key reasons for extending Transparent Global Register class is to enable UGI to process complex point cloud and BLOB data structure at store level. The GLIF-DC will then transmit the completed transaction details to GLIF in order to minimise network overhead between the store and GLIF.

Figure 7.9 UML Diagram of UGI
7.3.1 Ubiquitous Item Register (UIR)

UIR utilises components of GIR to enable interoperability with other supply chain networks and standards. At the same time, two Binary Large Object (BLOB) arrays were also added to the UIR class. The first BLOB array store the 3D point cloud presentation of the GIR, however, this is insufficient for object detection because different product can co-exist with the same packaging dimension. Therefore, the second BLOB array is incorporated to GIR to capture different binary images of the GIR, so that detected object could be validated using an OpenCV SURF library.

7.3.2 Ubiquitous Location Register (ULR)

ULR extends the components of GLR, but at the same time provides all the sensors mapping to UGI including both 3D camera and RGB Camera. Another important role for ULR is to enable UIR content to be mapped to ULR, therefore, as the user picks up an UIR item from the shelf, UGI would already know which item it is expecting to detect. If UGI fails to detect the UIR item, then it will attempt to compare the UIR with another UIR from the adjacent shelf and continue to span forward until a UIR is matched. This assumption assumes that the misplaced product is likely to be in close proximity to the correct shelf.

7.3.3 Ubiquitous Basket Register (UBR)

UBR is used to monitor the quantity and type of UIR that has been placed in the basket while the user is inside the store. The UBR is the result of extending the GPR, in which components of GPR are used to track “what is in the basket”. In order to validate that the item has been placed into the basket, the UBR check with UGI to check that the following conditions mutually exists:

a. User hand had entered a detection zone and a product (UIR) was detected and verified

b. User hand had entered the basket detection zone and the hand is empty after leaving the basket
In the event that the user decides to put back an item from the basket onto the shelf, the reciprocated process will be applied. However, since there are no camera mounts on the baskets, the system will have to totally depend on UBR records. Since the item can be removed from the basket at any time, the ULR will need to provide the correct camera mapping so that the item removed from the basket can be validated.

7.3.4 Ubiquitous Device Register (UDR)

UDR extends GDR to enable GDR devices to be accessed at a local network level, therefore, improving the overall performance of the UGI. UDR can also incorporate other sensor profiles and not be just restricted to fixed cameras. In a grocery environment, in which perishable items are required to be weighed, electronic scales can be integrated as part of the UDR function and event binding condition. As the user picks up the weighted product into the basket, the price conversion of the weighted item could be automatically associated to the basket checkout total.

7.4 Prototype in IGA

UGI differs from conventional track and trace architecture, in which the primary focus is on the interpretation of traceable objects and user’s interaction in a defined space (segment) that can be captured using multiple 3D cameras and sensors. The UGI is then used to filter for pre-defined gesture profile. Upon detection, the virtual event is raised, such as “item X being picked in location Y by Z person”, which can then be passed on to the physical systems. The ability to track objects without the dependency of embedding traceable technology such as RFID and barcode, means that UGI can be implemented in scalable multi-standards across the global supply chain network.

From initial testing, the RGB camera built-in the Kinect Camera (640 X 480 pixels 30 fps) is inadequate to reliably capture the BLOB from the shelf mounting position due to its low resolution. This can be overcome by adding a high resolution (1920 X 1080) RGB camera adjacent to each Kinect camera within the array. However, this may increase the computation time for Open CV SURF to process each BLOB and increasing the resolution may cause timeout issues which will have adverse performance effects to the UGI.
When more than two people are together in the same camera view, not all the users can be detected. This will create an issue for tracking the user’s location and detecting the user’s gestures within the store. However, the issue is more related to the limitation of the Kinect camera SDK rather than UGI model.

3D cameras can provide much faster user and facial detection when compared to conventional (2D) camera (Figure 7.10). Since user’s facial expressions can be easily translated into meaningful emotional states, such information could be valuable to product manufacturer, market research and other collaboration networks in the supply chain.

The image of the RGB taken from the camera will be relatively close to the shelf. Thus, the quality and focus point of the images obtain for BLOB detection are critical for high speed and accurate BLOB detection. Unfortunately, the current Kinect camera does not provide an autofocus function. A standard digital camera, including Kinect cameras, captures images based on the light that strikes sensor. The Lytro camera (http://www.lytro.com) captures light field data. The light field sensor records the entire light attribute, including colour, intensity, and direction from every light ray entering the camera, not just the part that strikes the sensor (Anthes, 2012). This additional data makes the images easier to manipulate. The image can be focused after the image is taken. At the time of writing, Lytro did not release any API or encoding standard for its camera. It is anticipated that with the assistance of Lytro, the BLOB detection performance can be greatly improved.
7.5 Conclusion

This chapter demonstrates the adaptability and interoperability of GLIF. It is possible to create a ubiquitous environment that enables various sensors to detect and monitor users’ behaviours within defined parameters without direct physical interaction. The advantage of 3D depth sensing cameras over existing conventional 2D cameras is the ability to capture point cloud from their infrared sensors to reduce the computation cost of image and video stream processing. This ability is then coupled with using NiTE computer vision middleware which translates the camera raw output into skeleton joints. It is important to note that UGI was implemented at a local network in order to reduce TCP overhead. All GLIF Global Register classes were extended with additional parameters to complement the UGI class. This experiment demonstrates the flexibility and reusability of Global Logistics Integration Framework.
Chapter 8 Discussion and future research

8.1 Introduction

The current global supply chain has three key problems in the areas of compatibility, adaptability and interoperability. In this thesis, a global integration framework has been proposed and tested. This work was done within the context of doctoral research. It is usable for some industries in this current form but there is still a lot of work to be done to make it truly universally applicable. This chapter will examine some of the ideas emerging from the research.

8.2 Virtualisation and Cloud Computing in Supply Chain Management

Traditionally, supply chain infrastructures were built on existing IT backbones that were managed locally in-house by supply chain network administrators. Current supply chain information backbones are built based on the assumption that communication between supply chain companies and their service providers will always be connected to the Internet. This assumption may not be correct for smaller supply chain firms who do not have the capability or the resource to provide such redundancy.

8.2.1 Impact of Virtualisation and Cloud Computing

Virtualisation can provide a cost effective solution that enables hardware consolidation with existing infrastructure. However, in Australia, the high hypervisor licensing cost and labour cost to hire external IT virtualisation experts to re-configure existing IT infrastructure can cost as much as purchasing new infrastructure. Furthermore, from previous experiments, some supply chain firms that utilised old databases such as Microsoft SQL 2000 suffered from performance degradation in a virtualised environment, thus, there is some resistance to adapting virtualisation in sectors of the supply chain. Nonetheless, hypervisors are computer software and are vulnerable to malicious attacks (Colp et al., 2011). In some cases, one of the milk distribution companies has decided to revert back to physical IT infrastructure, because of performance and security issues. Moreover, most supply chain firms lack the resource of in-house experts who can manage, maintain and update the virtual infrastructure.
The future research into better securing hypervisors will be an important topic for future researchers, as the damage is applicable to operating system, virtual appliance, application and data integrity. The effect of successful malicious attacks will be compounded and magnified in virtualisation environments. Most hypervisors utilised Open Virtualisation Format (OVF) that utilised Web Services (WS) implementation and hypervisors SDK to manage the virtual environments. WS SDK can create, update, clone and delete instances of virtual machines within the virtual environments. Therefore, it is paramount that the security layers of the WS are secure. A few of the ways that hypervisors could be to further improve to avoid a malicious attack include:

- Distributed Denial of Services (DDoS) attack
- Man In the Middle (MITM) attack
- IP Spoofing
- Port Scanning

However, for some supply chain firms who do have the resources to operate virtual IT infrastructure, the advantage of dynamic, on demand real-time resource are limitless. New platforms and application can be tested in a controlled environment and then deployed into production systems seamlessly. Virtualisation will ultimately change the way supply chain firms manage and view IT infrastructure.

Cloud Computing enables virtual infrastructure to be hosted and managed by third party vendors. XaaS (Anything as a Service) model enables cloud computing and business services to be delivered on a highly scalable pay-as-you-use arrangement. The key advantage of virtualisation and XaaS model is to reduce supply chain firms from over investing in large capital IT infrastructure that are expensive to purchase and maintain. Such physical infrastructures are often difficult to configure, maintain and secure. They constantly require the support from specific hardware experts with product knowledge, to ensure that there are no conflicts and compatibility issues across their entire systems. With XaaS model, the service providers are responsible for maintaining their network, hardware, operating system, backup and security. The supply chain firms then only have to maintain the
application layer and the virtual infrastructure that is highly manageable via XaaS provider’s web portal.

XaaS services, such as Virtual Private Server (VPS) enables supply chain firms to have access to scalable, high availability resources without having to invest in purchasing additional hardware. Since supply chain workload can be seasonal, therefore, the idea of having access to resources that can be dynamically scaled up or down will be appealing to most supply chain firms. However, significant research is still required to investigate different mapping methodology of XaaS services so that it can be packaged into end-to-end applications that can be reutilised in other industries.

8.2.2 Virtual Mobile Appliance

The idea of virtualisation can be extended into mobile devices. Today’s smartphones and tablets are now as powerful as a desktop workstation. They also utilise a powerful mobile operating system such as Google’s Android, Apple iOS, and Microsoft Windows 8 and are equipped with an array of sensors. The SDK (Software Development Kit) and API (Application Program Interface) enable applications to access the sensors within the operating system. Thus, virtualisation methodology can be used to consolidate and emulate costly proprietary supply chain peripherals such as a RFID, GPS, PDA with barcode and QR code scanner into today’s smartphones with a rugged case.

With new smart phones, GPS, mobile internet, camera and sensor technologies becoming readily available and affordable, many supply chain firms and SME are moving away from expensive ruggedize devices and are switching to consumer based smartphones with a rugged housing. Many of these rugged housing are tested to meet or exceed US Department of Defence Standard 810F, such as Griffin (http://www.griffintechnology.com/survivor) and Otterbox (http://www.otterbox.com). However, there are still challenges in developing universal cross-platform mobile applications. The current method of utilising cross-platform complier as a universal programming platform remains dependent on the smartphone device having constant connection to the internet. Today’s network coverage of 3G and 4G would not present an issue if the application was to be accessed in established cities and towns, however, in the scenarios which network coverage is an issue, the application will be
required to store the offline data to the smartphone device local storage. Current cross-
complier utilises HTML5, CSS3 and JavaScript as a universal programming language,
however, there is no official SQL standard for HTML5, currently, SQLite
(http://www.sqlite.org) is considered the reference implementation. However, SQLite is still
very limited in functionality when compared to other native SQL implementation, such as
MS SQL Server Compact (http://www.microsoft.com/en-us/sqlserver/editions/2012-
editions/compact.aspx).

One example of SQLite is that the maximum size of the database must be initiated with a
known maximum size when the database is declared
(http://docs.phonegap.com/en/1.2.0/phonegap_storage_storage.md.html). Further research
is required to develop secure, high-performance Relational Database Management Systems
(RDMS) for mobile devices that do not have the constraints of size specifications that can
be utilised within the HTML5 standard.

As other technologies such as augmented reality, smart shelf, NFC and auto-checkout
technologies begin to emerge, global supply chain systems should be able to quickly and
easily adapt to new technologies standards without having to change their existing
infrastructure and platforms, which is one of the main reasons RFID was not readily adapted
in the global supply chain.

8.2.3 Impact of ISA in Supply Chain

One of the biggest issues in managing the connectivity between different supply chain
systems is the ability to provide connectivity between key stakeholders. In many cases,
accurate information such as vessel and voyage schedule from stevedore companies will
need to be made available to the primary key stakeholders, like wharf cartage companies, in
a timely manner to enable them to execute their processes and update their clients with their
container delivery schedule, discussed in section 1.1.

VPS running Linux is more responsive and require fewer resources than the Microsoft
Windows operating system. However, nearly all supply chain applications in the
experiments, including VBS, are targeted to operating inside Windows operating systems
and in some cases, will only work with specific web browsers such as Microsoft Internet
Explorers. This is likely due to the web application dependency on platform API, such as
Microsoft ActiveX script. It is well-known that there are security and vulnerability issues with Microsoft ActiveX implementation (Egele et al., 2009), therefore, having the ISA operating Microsoft ActiveX in a virtualisation environment further reduces any risks to the rest of the enterprise network.

Another advantage of the ISA to be hosted using VPS is the ability to dynamically deploy teams of ISA to multitask time sensitive tasks, using ISA tasks managers. The ability to access the VPS API inside the ISA means other ISAs can be invoked while the primary ISA remains active to process some of the assigned tasks, thus, further reduce processing time. The speed and the accuracy of the ISA are also largely increased when compared to human operators. It is important to acknowledge that ISA will require to be recalibrated if the provider decided to alter any input interface. Thus, further research is required to develop an adaptive screen interface management layer for ISA, so that the field position can be automatically updated at run-time.

8.3 Expansion to global geo fence systems

It has been pointed out in chapter 2 that most of the existing frameworks are based upon physical RFID tags being read by RFID readers that are based on EPCglobal architecture. As products containing RFID tags move across the RFID readers, the location of the product 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 detailed information, for example, which door or gate their products were received. The main objective here is to verify that it has been received. Therefore, the RFID readers themselves can be emulated as a virtual appliance that can be accessed across both physical and virtual IT infrastructure. Thus, smaller supply chain firms would have the ability to insert tracking data to GLIF, therefore improve the visibility and efficiency of the global supply chain.

Current event geo-fence triggers are designed to operate on allowable time tolerance based on each jobs allocated driver, vehicle type, ETA and ETD. In the event of vehicle breakdowns, car accidents and unavoidable delays, the transport operators will have to manually update each jobs ETA and ETD for the geo-fence to trigger correctly. In the case of wharf
cartage case study, the time tolerance is relatively large (between 45 to 60 minutes each way). Further research is required to develop an adaptive time tolerance model that can dynamically update the time tolerance per job in real-time, thus, improving the efficiency and accuracy of the geo-fence systems.

There are new concepts and implementation of mobile data, such as Google Balloon, that enable Wi-Fi signals to be relayed from ground infrastructure to remote locations that do not presently have access to the internet. In the case of natural disaster, Google Balloon technology could be deployed to enable mobile internet access in which existing ground infrastructures are offline. Since the internet access can soon be accessed anywhere around the world, the concept of the proposed geo fence system can also be reapplied to other sectors of the industry, such as monitoring the target points of a shipping voyage, to ensure that the vessel is moving on schedule.

8.4 Bandwidth and Data Utilisation

QDBC can reduce the TCP overhead between end points and hosted services. Despite massive improvements to mobile network speed and coverage over the last decade, it would be unfeasible to assume that all wireless end points will have sufficient bandwidth to support the transmission of EPCglobal events. Event objects in Fosstrack EPC-IS database transmit all EPCglobal events in XML. At pallet level, there could be a few hundred of RFID tags being scanned simultaneously, thus, there can be a very large amount of XML Event objects being transmitted from the end-points to the hosted EPC-IS database. The efficiency of the QDBC can be further improved by converting the XML to JSON before the queued compression is applied.

QDBC is not exclusive to RFID applications, it can also be used where low bandwidth at end-points is present. The application for QDBC includes: camera sensors, GPS and other built-in sensors of smartphone devices.

Using pipe-paring can improve efficiency and security over any cast. Since the connections are direct between endpoint- ISP to ISP-host, it removes the dependency of the DNS server to perform load-balance. Pipe-paring is being used when real-time data is required such as in VoIP applications. However, there aren’t any reasons why pipe paring cannot be used with QDBC to further improve response time.
Further research should investigate different methods of providing secure and efficient access to cloud service end-points, as well as developing new algorithm and data compression models to improve the efficiency of delivering cloud services between end-points.

8.5 Implementation of Global Logistics Integration Framework (GLIF)

Data privacy, security, accessibility and business continuity are some of the key issues that faced SMEs who are planning to decommission their data centres to relocate to cloud service providers. In February 2013, UK datacentre 2e2 who provided hosting facility to a number of cloud vendors filed for bankruptcy. The administrator demanded that the customers of 2e2 paid an upfront fee of over £1 million to keep the datacentre open (for more information visit http://www.computing.co.uk/ctg/news/2242625/2e2-pay-up-gbp1m-now-or-we-close-the-datacentre). Certainly from an academic aspect, cloud computing and virtualisations are the most cost effective methods of implementing scalable and manageable IT environments. However, the question of trust and sustainability remains key pivotal questions for any SME to proceed with cloud computing implementation.

Many consumer devices are also heavily dependent on cloud services, from streaming music using Pandora (www.pandora.com) to monitoring energy usage using Google Power Meter. In September 2011, Google decided to retire their Google Power Meter project, due to low market up take, thus, leaving many people with legacy power monitor devices. This example shows that rapid services depreciation and unpredictable product life cycles are part of the contributing factors that explain why certain supply chain firms are not willing to “move with the time” in order to transform their IT systems to cloud computing. Apple, in 2012, also decided to retire Google Map from their iOS mobile operating systems, so that they can gain market share with their own mapping application.

Thus, applications developer can no longer depend on a single platform or PaaS. Moreover, future applications will need to be agile and will need to have the ability to adapt rapidly to the ever changing cloud computing landscape. Many of these requirements are reflected in the Transparent Framework, by utilising the internet as the foundation, different sensors, services, infrastructure and platform can be collaborated together to create an agile and
scalable environment that is not limited to global supply chain management. The supply chain industries in the case studies, overall welcome the proposed GLIF framework, because it encourage smaller SCM firm to participate in information collaboration with minimal capital costs. However, while the Transparent Framework may have solved some issues with single platform dependency, further research work is required to develop the event binding logic that enables the interpretation when sensors interact with mapped objects in global registers. The event binding discussed in this thesis is just an example of what can be achieved, however, if more event binding logics are developed, the technology could be applied to other industry sectors.

8.6 Deployment of Ubiquitous Gesture Interpreter (UGI)

The Ubiquitous Gesture Interpreter (UGI) is an implementation of GLIF that utilises Object Oriented Approach, the base objects in Global Registers are extended to store specific functions that incorporate different types of technologies and sensors to create a new class of smart shelf technology. In the experiment in Chapter 7, UGI utilised two groups of sensors. An array of 3D cameras were used that detected user skeleton joints with the aid of NiTE computer vision middleware that translated point cloud data into meaningful skeleton joints and an array of high-resolution cameras that utilised the OpenCV SURF library were used to detect BLOB objects that were stored as part of the GIR extension.

The performance of the 3D camera using NiTE middleware to detect skeleton joints was approximately 25-30 frames per seconds, while the OpenCV SURF can detect the BLOB from the high-resolution camera in approximately 1-3 seconds, which can be inadequate for fast moving objects. Thus, to improve the utilisation of local CPU resources, the OpenCV SURF is only activated when either user hand joint enter and leave a defined segmentation zone while holding an object. The sensors event binding in UGI is very similar to those used in the Transparent Framework geo-fence detection. As mentioned in Chapter 7, other sensors such as Lytro camera can also be incorporated into the UGI to improve responsiveness.

UGI sensors are made from very basic components, apart from Microsoft Kinect Camera, which is essentially a digital camera, with an infrared emitter and an infrared camera to capture the point cloud data, the high resolution camera is used because the image resolution obtained from the Kinect Camera is inadequate for OpenCV SURF to detect BLOB images.
The focus to UGI should not be based only on camera technologies, but the ability to collaborate data obtained from different sensors and interpret the subject’s gestures based on the concept of event binding logic in GLIF.

New intelligent sensors are emerging such as Lytro camera and LEAP Motion sensors that capture hand gestures (Figure 8.2). They are also becoming more complex and often consist of two or more native sensors. The CPU and the built-in middleware are responsible for the net interpretation results; therefore, it can easily be updated at the software level. Eventually, these intelligent sensors will become very affordable, highly networked and embedded everywhere. Future research should be based on further collaboration of intelligent sensors so that it can be mapped into UGI, furthermore, a universal gesture library should be developed and incorporated into UGI to enable seamless adaptation of intelligent sensors, thus, further reducing the load on UGI event binding managers. Furthermore, new intelligent UGI event binding model should be developed to enable real-time calibration of gesture learning to improve the robustness of UGI systems.

Figure 8.1 LEAP Motion Gesture Sensors
Chapter 9 Conclusion

The research was aimed to develop an end-to-end global logistics integration framework that is agile, scalable and adaptive. This thesis examined the key components of logistics information technologies and systems used by various parties in the global supply chain. Successful technology adoption relies on a flexible infrastructure design. End to end global supply chain network information integration and collaboration cannot be dependent on a single technology medium or fixed standard. This research has made significant contribution to knowledge in the following areas:

- Data capturing devices and emulation model
- Interface with legacy system via ISA
- Interoperability of developed framework
- End-to-end integration of GLIF

Each of these areas are discussed in the remaining sections of this chapter.

9.1 Characteristic of Data Capturing Devices and Emulation Model

In this thesis, the emulation model for both fixed and mobile devices were created using powerful smartphones, however, high quality internet connections are required at each endpoint to facilitate VMA and event driven data collaboration. However, the assumption is that all end-points connect to cloud services will be facilitated by fixed uninterrupted high speed connection. In many cases, connectivity to end-points are facilitated by low bandwidth dial up connection or GPRS and 3G wireless mobile data connection, that are not suited for real-time systems. The two proposals to optimise bandwidth were discussed in this thesis. Sub-Cloud Service (SCS) is based on a multi-hosted cluster environment, in which each access point are automatically routed to the nearest sub-cloud host, based on geographical as well as ping and jitter results. Utilising pipe-paring and data replication, the clients are then redirected to the most appropriate hosts. In the event where the location clients had shifted during active connection, the host member can seamlessly redirect the client connection to a new host member that offers improved performance. Queued Burst Device
Compression (QBDC) model can heavily improve the performance of end-points using post-data compression process. As demonstrated in chapter 5 with Fosstrack EPC-IS database, the XML Event Object is converted into JSON Event Object then compressed and sent at predefined intervals. The process is then reversed at the host connection which compressed data are decompressed and JSON Event Object is converted into XML Event Object before it is processed, thus, reducing the TCP overhead between end-points. To evaluate and compare different elements of the proposed framework, some individual experiments have been carried out separately as described in Chapters 5, where the network performance has been compared with other technologies, and in Chapter 6, where the cost of implementation of several options has been evaluated.

9.2 Interface with legacy systems

There are many legacy propriety heterogeneous supply chain systems that are operational today. Many of these heterogeneous systems do not have the Application Program Interface built-in nor can they be integrated with other systems. Therefore, human operators are required to manually enter data between heterogeneous systems. Manually re-entering data between systems can cause system misalignment and data integrity issues. The ISA had been developed and implemented to synchronised data between TMS and stevedore vehicle booking systems. With the assistance of Virtual Private Server (VPS), multiple instances of ISA can be rapidly deployed using VPS API. In the event in which time critical tasks are assigned to ISA, the ISA manager that is built-in to all ISAs can invoke other ISA instances to perform load balance to ensure that the time critical tasks are completed on time. Section 3.4 demonstrated the ISA ability to interface with each stevedore organisation to retrieve time sensitive shipping schedule and container status from their legacy systems.

9.3 Interoperability of developed framework

As mobile devices evolve, they are becoming more powerful and resourceful due to the increasing integration of intelligent sensors. As a consequence, mobile devices like smartphones and tablets are as powerful as desktop workstations from a few years ago. Today mobile devices are also fulfilling the role of what was once dedicated to only desktop workstations. This flexibility increases their demand, resulting in further technological
advancement and competitive pricing between mobile device vendors. Therefore, the mobile devices can be used to replace the role of legacy data capture devices.

This thesis leverages the capability of cross-complier that enables application developer to have direct access to the mobile device sensors, therefore, the concept of Virtual Mobile Appliance (VMA) can be realised. VMA enables mobile device to perform as virtual hosts in which different business logics and workflow can be applied, regardless of the mobile device operating systems or platforms. Data obtained from intelligent sensors in mobile devices can be accessed via VMA so that it can also be processed at runtime or post-processed with cloud services, therefore, enabling VMA to emulate the function of legacy devices with the aid of its embedded intelligent sensors. The experiment with Frosster in section 3.6 highlights the cost benefit of VMA over mainstream legacy devices, as well as obtaining operation efficiency from real-time synchronisation of cloud services.

A new real-time geo fence model was created by utilising the GPS sensors residing in VMA, GPS data can be transmitted to cloud based, Web Service Application (WSA) which can be used to process data to FMS and other logistics systems. In the case when logistics infrastructures like RFID are absent, events generated from WSA can also be integrated with other systems, such as EPCglobal and other RFID networks to confirm the delivery of freight.

The thesis presented a unique model that enables real-time GPS data to be synchronised with TMS and WMS. As a result of event binding between VMA and logistics systems, real-time alerts and events can be created and transmitted to key stakeholders and trading partners. Further improvements to WSA can be established by incorporating device state and time conditions resulting in improved accuracy to event detection. The experiment with Action Transport Logistics wharf cartage operations in chapter 4 highlights the benefit of real-time monitoring and time condition with pre-allocated jobs for bulk-runs in a wharf cartage operation.

9.4 End-to-end integration of global logistics framework

The design and development of Global Logistics Integration Framework (GLIF) leverages virtualisation technologies and cloud computing to create a foundation framework that enables the integration of fixed, mobile and virtual devices with different supply chain systems and standards. The mapping of sensors, locations, items and packages in GLIF are
refer to as “Global Registers”. As data is obtained from each global register, it is analysed with GLIF’s Event Binding Manager (EBM) which interprets the interaction of instances in the global register’s mapping, so that events and/or device states can be generated to emulate the event generated by physical devices. The GLIF consists of a collection of API library that can be accessed and reused to develop new frameworks based on Object Oriented Approach (OOA).

A model coded name “Transparent” has been developed that demonstrates the utilisation of alternative technologies such as Quick Response Code (QR Code), Global Positioning System (GPS) and other peripherals within mobile devices can be coupled with pre-defined business logics to emulate events triggered by physical RFID tags.

The implementation of GLIF in wharf cartage organisations can improve the efficiency of container transportation amongst competing organisation. The collaboration of information obtained from GLIF geo-fence with time constraint enables accurate, real-time tracking of empty container between wharf cartage organisations for import and export functions. With permission from the shipping line, an empty import container can be used as an export container and utilisation of the empty container is also open to other nearby wharf cartage organisations, therefore, creating synergy and efficiency for both wharf cartage organisation and shipping line by reducing the amount of trips to an empty container park.

The reusability of the GLIF is demonstrated with the Ubiquitous Gesture Interpreter (UGI) model. In chapter 7, UGI was prototyped using the output from Microsoft Kinect Camera and a high resolution camera at a IGA grocery store in Australia. Using the NiTE computer vision middleware and Microsoft Kinect SDK, humans’ joints in each camera view can be promptly detected. As either hand joint reaches into a shelf, a pick gesture is detected. These gestures enable UGI to invoke any predefined processes such as product validation and associate the products to the user's basket. When combined with an array of high-resolution PTZ camera, UGI was able to accurately record and validate the product in the user’s hand. Not limited to camera sensors, UGI can also be used with other motion gesture capture sensors such as LEAP motion sensors. The UGI demonstrated that GLIF can be extended so that new sensor technology can be incorporated with UGI, thus, resolving the issue of compatibility, adaptability and interoperability for global logistics supply chain systems.
References


Appendix 1

Publication till date


