A solution for Integrated Track and Trace in Supply Chain based on RFID & GPS

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Abstract

The RFID and positioning system technologies are the key enablers for logistics supply chain visibility and tracking. While RFID is useful for inventory and material handling processes in warehouses, as soon as the RFID-tagged goods leave the warehouses, one often lose track of them until the next loading docks. In-between the sending and receiving points, there is often no tracking of the cargo which may be at risk of missing, off-loading and delay especially if the cargo is critical or perishable. The positioning system such as GPS (Global Positioning System) is usually used to track the vehicle; however it only provides a geographical location without associating business process info. The present research targets at a total solution architecture for seamless, global wide, track and trace system for logistics supply chain using an integrated RFID and positioning system technologies. The research involves development of a new solution for track and trace using both RFID and GPS, integrated information management models and web-based services. It can integrate RFID events with geographical location information and associate them with the cargo, so that the cargo can be seamlessly tracked and traced.

1. Overview

Supply chain management involves coordination and collaboration of activities among supply chain members including suppliers, manufacturers, distributors, intermediaries, third-party service providers, and customers. It encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management activities, such as demand forecasting, materials requisition, order processing, order fulfillment, transportation services, invoicing and payment processing. RFID technology can be used throughout the supply chain to provide visibility and improve the processes. Some applications that will benefit from RFID include warehouse management system (WMS), transportation management system (TMS), enterprise resource planning system, asset management system, inventory management system, production scheduling system, order management system, etc.

RFID systems use wireless radio communication technology to uniquely identify tagged objects or people. There are three key components of an RFID system, namely tag, reader and middleware. The tag and reader communicate information between one another using radio waves at various frequencies, including LF (125-134 kHz), HF (13.56 MHz), UHF (860-960 MHz), microwave (2.5 GHz and above), etc. When a tagged object enters the read zone of a reader, the reader will signal the tag to transmit or backscatter its stored data. Tags can hold many kinds of information about the objects being attached, such as serial numbers, time stamps, configuration instructions, etc. They can be used on individual items, cartons, cases, pallets or containers.

While RFID is useful for inventory and material handling processes in warehouses, as soon as the RFID-tagged goods leave the warehouses, one often lose track of them until the next loading docks. In-between the sending and receiving points, there is often no tracking of the cargo which may be at risk of missing, off-loading and delay especially if the cargo is critical. Tracing delivery status for customers has been one of the main hassles for logistic companies because it often involves many parties to call and check for the updated status of the cargo in transit. These parties include sales executive, customer service, operation, warehousing and even transportation staffs of both sending and receiving sites. This no doubt consumes much time or resource and distracts the normal routines of the parties, since otherwise they may focus more on their respective roles. For instance, sales executive could concentrate more to seek for higher sales rather than merely busy answering customers queries, e.g. “Has my cargo arrived?”, “When is my cargo arrived?”, etc.

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For tracking of vehicles – not the cargo or goods themselves – trucks on the roads (or locomotives on rails or ships in oceans), the technology currently employed by organizations is GPS. To our knowledge, GPS has not been used for tracking of goods down to the level of pallets, cases, cartons or (ideally) items in supply chain. It is primarily used in transportation to track assets including vehicles and other expensive equipments. In the case of a truck breaks down, it is possible to locate the truck and get the shipment moving again in a short time with GPS. GPS systems work by calculating the distances from a receiver to a number of satellites. Usually four satellites are used to determine the location accurately in the GPS positioning module. Modern GPS navigation systems also provide additional modules including digital map database, map matching, route planning and guidance, and wireless communication. When indoors, GPS receivers can no longer communicate well with satellites to provide accurate location information.

Often the two RFID and GPS technologies are used by different parties as separate entities with their own features and purposes. If both technologies can be combined to become one integrated system to track and trace goods in supply chain, greater gains can be achieved. In particular, GPS mapping systems when linked to enterprise resource planning could facilitate inbound and outbound logistic scheduling. The result is not only seamless visibility, but also increased reliability of inbound and outbound load/unload decision making, increased transport capacity and optimization in urban areas, automatic exception reports, dynamic goods routing, on-line shipment decision support, etc. The integrated RFID and GPS technologies represent our original approach which complements the strength of RFID and its information storage with GPS for global positioning to provide complete resolution for tracking supply chain.

Several integration issues remain to be resolved at both hardware and middleware levels. To integrate GPS and RFID systems, the RFID reader/tag is to be used together with GPS receiver. Their data also needs to be captured, communicated and written to a database correlated among the receiver and tags. Further nesting of both technologies will allow the information of RFID tags to be transferred to GPS receiver. If some of the tags have sensors to monitor environmental conditions for physical parameters like temperature, humidity and shock, etc., more detailed data may be collected real time especially for perishable or high-security goods. The GPS receiver could then send out not only its geographical location but also all relevant information of cargo being shipped to the inventory databases. All the information could also be uploaded and displayed over the web through query and capture interfaces.

The present research targets at a total solution architecture for seamless, global wide, track and trace system for logistics supply chain using integrated RFID and GPS technologies. The research involves development of new solution for track and trace using both RFID and GPS, integrated information management models and web-based services. Hardware development is not the focus in the scope of this presented work. The proposed solution can integrate RFID events with geographical location information and associate them with the cargo, so that the cargo can be seamlessly tracked and traced.

2. Literature Review and Analysis

RFID is being adopted more by industries. As we know, Wal-Mart is one of the pioneers incorporating RFID in its retailing and supply chain system and Gillette is one of the first eight companies to participate in the initial RFID pilot with Wal-Mart. They have used RFID technology to track their inventories as they move through the supply chain, from the manufacturer to the distribution center, the retailer stock room, and then to the shelf on the sales floor of the store. DODS of US is also the early adopter of passive RFID to solve US military's huge logistics challengers [1]. To facilitate global supply chain track and trace based on RFID, EPCglobal standard is developed. Some system vendors and main players develop systems to promote the EPCglobal. For example, Tibco, IBM and VeriSign jointly developed demo systems for Product Authentication Scenario and New Product Visibility [2]. Intel introduced the connected Digital supply chain in 2005, in which RFID in EPCglobal is the evolutionary enabler for optimizing the supply chain that facilitate the acquisition, filtering, aggregation, and distribution of supply chain data for Goods Movement Visibility [3]. OAT partnering [4] with Intel [5] also developed the Resolution Supply Chain solution from OAT which targets a high-resolution view of product movement across the extended supply chain based on OAT EPC-IS Edge Server and Intel processors. Sun plays its role as part of the Sun™ EPCglobal initiative by developing the system architecture to integrate real-time data flowing in from existing business processes and back-end enterprise systems using RFID tags to address large-scale implementations in enterprises [6]. Oracle has also developed the EPCIS-compliant Information Services database for storing RFID data and Discovery Services for searching the data in EPCglobal throughout the supply chain [7]. There are some other systems. RFID Compliance Express is the RFID-based tracking solution from Bea Weblogic [8] leveraging on EPCIS standard and RFID technology. Electronic Pedigree (E-Pedigree) [9] solution is targeted at pharmaceutical industry track and trace to combat counterfeit drugs.

GPS has been well known and has wide adoption. It has been used for locating and tracking vehicles, items

and even people. Integration of RFID and GPS for cargo track and trace in supply chain is attracting more attention now [10]. Study [11] has been done to show the importance on real integration of e-tag, RFID, GPS, GRPS and internet. A system "Intelligent Store-INTELSHOP" is reported based on RFID and GPS to facilitate searching the products on the store's shelf [12]. Its application is not a supply chain scenario. A healthcare system is reported to track patient using RFID/GPS [13], but this research mainly addresses security and privacy issues when accessing medical data.

Few reports can be found in this area and event less reports can be found about the work of integrated track and trace solution based on RFID and GPS for supply chain at the level of pallets, cases, cartons or (ideally) items.

3. Proposed Solution

To fill in the gap, we propose a total solution architecture using integrated RFID and positioning system technologies for seamless, global wide, track and trace system for logistics supply chain. EPCglobal standard is employed in RFID tracking. The solution architecture is shown in the figure 1 and it consists of the following parts.

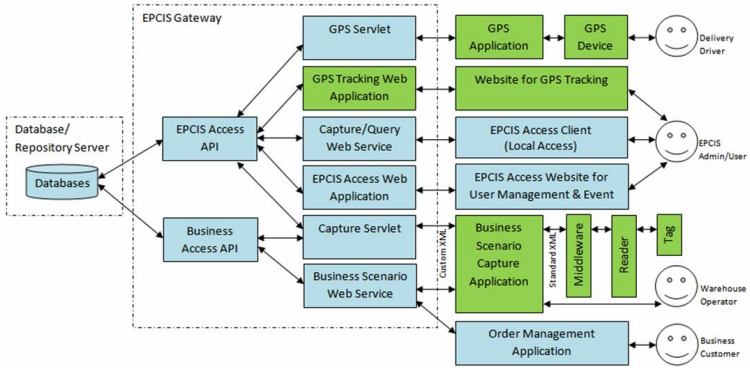

Figure 1. Abstract View of Solution Architecture

- Integrated information management model with EPCIS and system database

An integrated information management model is designed here to manage RFID events and GPS data. It is consists of EPCIS and system database as well as EPCIS gateway.

EPCIS is the key component in the EPCglobal framework. It provides standards to capture, store and access RFID events. It consists of RFID event repository, event capture interface and query interface. However standard EPCIS database is designed for managing RFID events only. In our integrated information management model, we design the database so that it can manage RFID events, GPS data and their association as well as critical business information as shown in the figure 2 below.

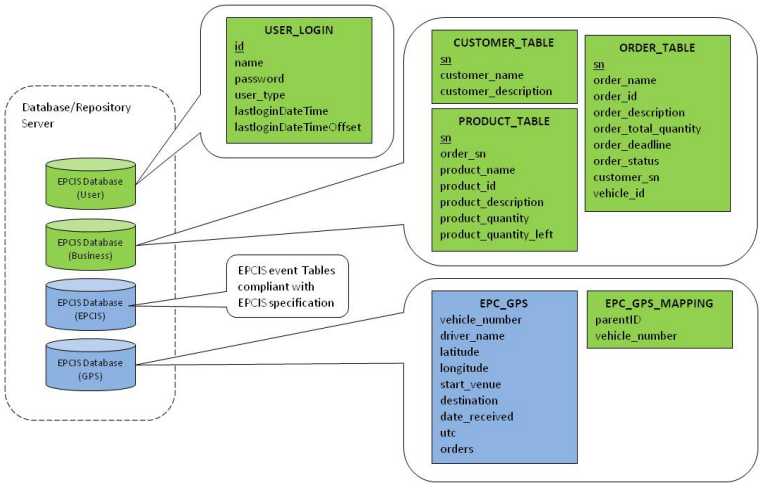

Figure 2. Design of database for integrated information management

- EPCIS Gateway

The gateway is designed to provide unified interface to capture and retrieve the integrated information of EPCIS and GPS for external applications (refer to Figure 1) such as capture application, mobile client system and tracking system as well as enterprise systems. The interfaces are designed based on web-service technology which allows to be loose-coupled and universal accessible. For security purpose, it also provides authentication service to control the access to the data stored in the database.

- RFID Capture application and middleware

The capture application is designed basically to get RFID data fed from middleware and convert to EPCIS events by adding business context and store them into EPCIS through EPCIS Gateway. Each capture application can be configured and assigned with a particular business scenario in the overall business process, such as "picking up", "shipping out" etc..

The middleware resides lower level of capture application in this solution architecture. It is designed here to drive RFID reader to communicate with tag. In this design, the middleware is only to retrieve tag ID without accessing user memory. The design of the middleware follows the EPCglobal standards.

- GPS capture client running in mobile device

The GPS capture client is designed to run in the mobile device. It can communicate with GPS module to get the data on the geographical position. The mobile device should have communication capability through

GPRS or Wi-Fi. In the scenario of our solution, a vehicle is equipped with a mobile device with a GPS receiver (which could be built-in or external module). The GPS capture client will interface with it and transmit data together business context information to a central server through GPRS. The data will be stored into database through EPCIS gateway so that other applications from can access and use them for various purposes such as business information presentation for vehicle tracking.

- Business information presentation

This is designed to deliver all business information to the user in a friendly, interactive way through web contents to improve the track and trace. It presents not only business order information, but also geographical location of items based on GPS data as well as process status based on EPCIS events.

The proposed solution enables the seamless, global wide, track and trace in supply chain. During the process in the supply chain, the real-time information about the product can be captured through the proposed solution of integrated RFID and GPS so that the product can be tracked and traced. This allows companies to have full real-time picture about the product flow through the supply chain. It also can minimize the risks such as product counterfeiting and lost as well as facilitate logistics activity including empty repositioning.

4. Solution Prototype

A prototype is designed and developed based on proposed solution architecture for the business scenario as shown in Figure 3. We use JAVA as development language and Microsoft SQL Server 2008 Express as database.

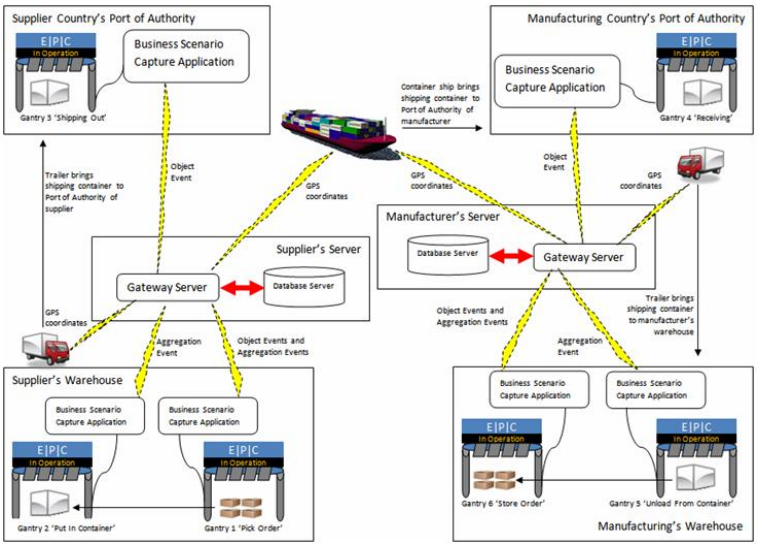

Figure 3. Prototype business scenario

The business scenario illustrates a type supply chain process. It starts from supplier's order picking & palletizing, uploading to container and shipping out till manufacture's receiving, unloading and storing. There are totally 6 logical reader points setup in the process. Details please refer to Table 1. RFID tags are tagged to items, pallets and containers. A mobile device is equipped to vehicle or ship carrying the container. There are 2 EPCIS and gateway servers are setup, one for supplier and the other for manufacturer. Events captured by Gantry 001 – 003 are stored in supplier EPCIS while events captured by Gantry 101 – 103 are stored in manufacturer's EPCIS.

Each reader point has a capture application for that particular business step. It will capture and generate events and send to EPCIS through gateway server. Figure 4 shows the GUI of captured application developed.

Table 1. Logical reader point and event definition

Reader Point	Biz Step	EPCIS Event	Biz Location
urn:epcglobal:epcis:readpt:fmcg:readpoint001	urn:epcglobal:epcis:bizstep:fmcg:Pick_Order	Object Event & Aggregation Event - Pallets' (Product) SSCC EPC & Items' SGTIN EPC	urn:epcglobal:epcis:bizlocation:fmcg:SupplierWarehouse
urn:epcglobal:epcis:readpt:fmcg:readpoint002	urn:epcglobal:epcis:Disp:fmcg:PackIntoContainer	Aggregation Event - Container's SSCC EPC & Pallets' (Product) SSCC EPC	urn:epcglobal:epcis:bizlocation:fmcg:SupplierWarehouseExit
urn:epcglobal:epcis:readpt:fmcg:readpoint003	urn:epcglobal:epcis:bizstep:fmcg:Shipping_Out	Object Event - Container's SSCC EPC	urn:epcglobal:epcis:bizlocation:fmcg:PortOfSgAuthority_A
urn:epcglobal:epcis:readpt:fmcg:readpoint101	urn:epcglobal:epcis:bizstep:fmcg:Receiving	Object Event - Container's SSCC EPC	urn:epcglobal:epcis:bizlocation:fmcg:PortOfUsAuthority_B
urn:epcglobal:epcis:readpt:fmcg:readpoint102	urn:epcglobal:epcis:bizstep:fmcg:Unload_From_Container	Aggregation Event - Container's SSCC EPC & Pallets' (Product) SSCC EPC	urn:epcglobal:epcis:bizlocation:fmcg:ManufacturerWarehouseEntrance
urn:epcglobal:epcis:readpt:fmcg:readpoint103	urn:epcglobal:epcis:bizstep:fmcg:Store_Order	Object Event & Aggregation Event - Pallets' (Product) SSCC EPC & Items' SGTIN EPC	urn:epcglobal:epcis:bizlocation:fmcg:ManufacturerWarehouse

Upon shipping out, the capture application will also associate EPCIS events with the vehicle shipping the cargo. During the process of transportation, the mobile device in the vehicle running the GPS capture client will regularly sent to the EPCIS gateway server through GPRS the geographical location together with the container identity and order info. Figure 5 shows the GUI of GPS capture client.

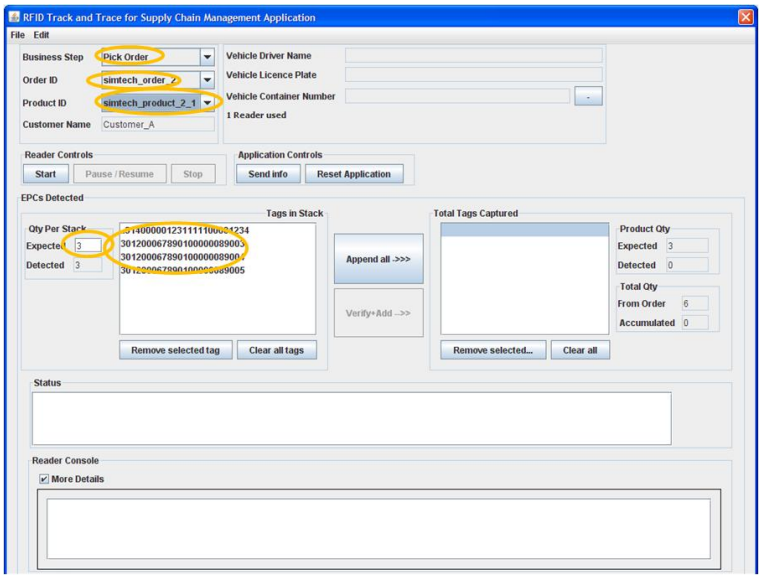

Figure 4. Capture Application

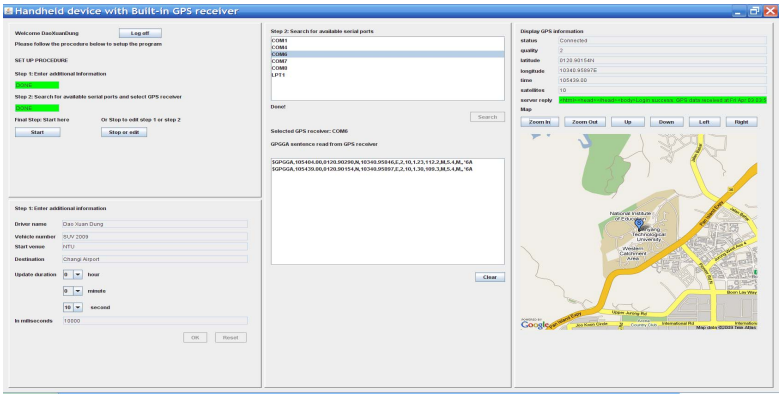

Figure 5. GPS capture client in mobile device

Based on the business information, RFID events and GPS data that are captured and stored integratedly through the EPCIS gateway, they can be retrieved and viewed through the rich web-based business presentation client. It can show graphically the real-time vehicle location, cargo loaded on it and order information as well as process status identified by EPCIS events as shown in the Figure 6. The companies can search and check online anytime to track their vehicle and cargo by giving business order number, product type and customer number.

The solution has attracted interests from companies in logistics and manufacturing to adopt the technologies developed. Our future work will improve the solution based on companies' feedback and requirements as well as refine the integrated information management model through further R&D.

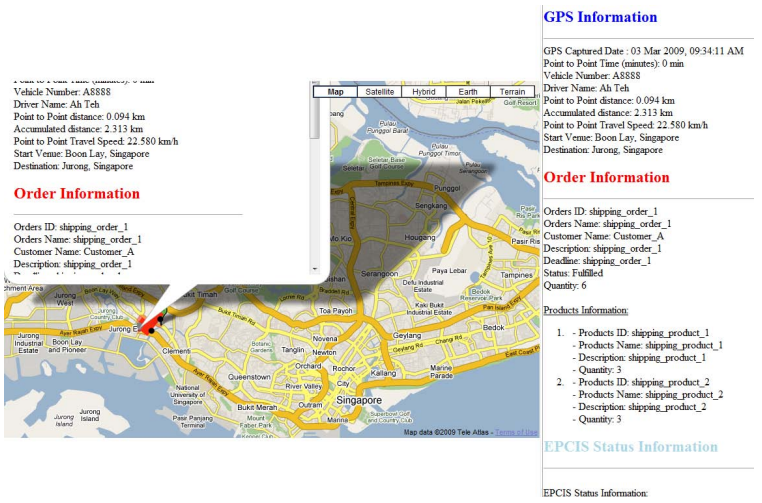

Figure 6. Web-based vehicle and cargo tracking

The overall detailed order information and status in the supply chain process can also be monitored through the order management GUI shown in the Figure 7.

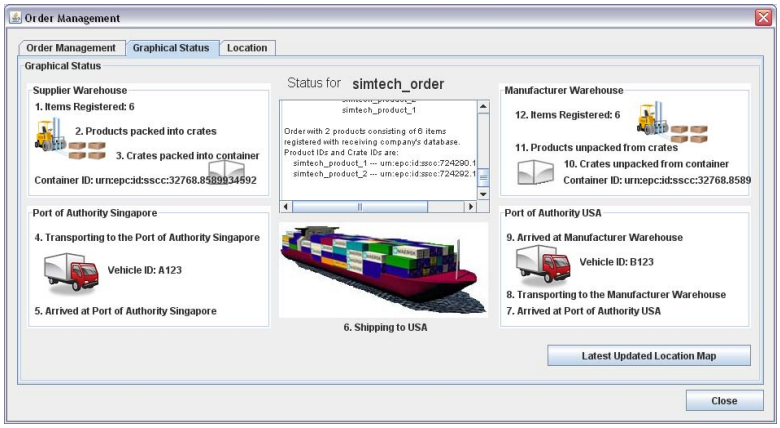

Figure 7. Real time order status

5. Conclusion

The synergized hybridization of RFID and GPS will feature the benefits of both systems in process tracking and outdoor positioning. They complement each other and provide seamless track and trace in logistics supply chain. They would define new technology and service trend in logistics industries. Currently few reports can be found about the integrated track and trace solution based on RFID and GPS for supply chain at the level of pallets, cases, cartons or (ideally) items. The paper fills in the gap by proposing a total solution architecture using integrated RFID and GPS technologies. A prototype

system has been developed based on the proposed solution architecture. It can be found that the proposed solution can enable seamless, global wide, track and trace for logistics supply chain. Given certain reference number such as business order, product type, customer or shipment number, companies could check online anytime to track their cargo. Tracking offers not only shipment status in the form of vehicle departure, arrival, and plain routing only, but also more value-added, detailed geographical location plus business order information as well as business process status in real time. The outcome can minimize missing cargo or off-loading and reduces backlogs, and also can enable customers to improve planning, make better decisions/controls across supply chain and hence increase their satisfaction.

Acknowledgement

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