Development of a smart port logistics service platform

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Abstract

The nature of port logistics requires global visibility and traceability. However, the traditional RFID technology still applied cannot meet these demands. There have been recent attempts to apply technology such as IP-USN or M2M in port logistics but they have faced challenges of the prerequisite of network composition and immense communications at the base where a grand number of containers are installed. Also, the stakeholders are recently demanding for technology and methods that respond in a more aggressive manner. To meet these demands and resolve the issue, this study suggests an IP-RFID-based smart port logistics service platform. The IP-RFID-based smart port logistics service system resolved the communication problem by separating the smart RFID tag and AP, which allows internet connection, from the tag. Also, tag control using bilateral communication enables active response to accidents such as fire, explosion, robbery, etc. of tagged containers. The tags connected with thermo-sensors, humidity sensors, pressure sensors, GPS, etc. are attached to the containers insuring global visibility and traceability, key factors in logistics, by obtaining desired real-time information regardless of time and location. The IP-RFID-based smart port logistics service platform not only accommodates these various demands but also is designed to solve possible future problems.

Keywords: *Port Logistics System, IP-RFID, Service Platform*

1. Introduction

Countries with globally important ports are engaged in various activities for the improvement of logistics systems including increased efficiency in container cargo management system and improved port operation information system by utilizing the latest information technology that composes a new social foundation, the combination of telecommunication and computers. Also, with the globalization of corporations, efficiency in global logistics management systems has risen as the most important factor in determining the firm's competitiveness; in pursuing international and global management, the value of SCM(Supply Chain Management) for competitive management in overall logistics fields by establishing global production · logistics network has elevated. Therefore, the perception of the efficient management and application of real-time information on the location and status of container goods in terms of improved transparency in logistics management, logistics cost reduction and increased company competitiveness, speed and accuracy of logistics information, etc. is on the rise. Efficiency of port logistics with information technology can contribute greatly to improving global SCM through rapid and accurate information processing at the level of individual firms and reducing investment costs and promoting logistics service satisfaction to increase the competitiveness of ports and corporations by enhancing the availability of national logistics and port facilities at the national level.

Ports function as transition and buffer between means of transport as the middle ground of mass marine transportation and little land transportation. A combinatory location as a station for logistics, production, livelihood, international trade, and the economic growth of the hinterland, ports are gaining importance. Currently, the RFID/USN(Radio-Frequency Identification/ Ubiquitous Sensor Network) technology in port logistics is applied in only a limited number of fields, i.e. application in the general process of port logistics awaits overcoming technological challenges. Recently, studies on global tracing and monitoring of RFID-attached containers are conducted in Korea regarding this matter. For readers to trace the movement of containers using the essential pre-existing RFID technology, readers must be installed all over the world and therefore, RFID technology combined with sensor networks is applied. However, as this USN-based technology requires full composition of sensor networks and M2M(Machine to Machine) communication such as USN in mass container-focused areas (container terminals or container yards) involve numerous problems in terms of communication infrastructure. Therefore, this study proposes a RFID/USN technology-based service platform that solves these problems and provides information by monitoring the location and internal status of global containers.

Also, a unilateral detection and status monitoring of cargos cannot meet the demands of various agents of port logistics. For example, in emergent cases including fire and explosions, measures to handle these situations are necessary; tags or sensors attached to containers require bilateral not unilateral communication. The function of tags and sensors also need to be simplified; tags and sensors should be controlled remotely to perform new functions. Also, for easy and economic realization of bilateral communication, IP infrastructure needs to be utilized. Smart devices based on IP, or smart tags and sensors are required. These will be defined as smart port logistics system in this article.

2. Reference review

2.1. RFID/USN and IP-USN

For high-speed information delivery, automation of information input methods into computers is essential. The technology that realizes this is commonly known as AIDC(Automatic Identification and Data Capture) technology and RFID/USN, the latest technology of AIDC, is the critical technology element in implementing automatic processing systems for automatic online acquisition of product-related information and processing that excludes any human handling or decision-making.

RFID is the use of a wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object, for the purposes of automatic identification and tracking. Some tags require no battery and are powered and read at short ranges via magnetic fields (electromagnetic induction). Others use a local power source and emit radio waves (electromagnetic radiation at radio frequencies). The tag contains electronically stored information which may be read from up to several meters away [1].

Research and development of the basic technology for commercialization of RFID began in the 70s and was applied in logistics management at the manufacture sites by the 80s [2 ~ 4]. By mid-90s, foundation for full-commercialization began to take form as international standards were discussed at ISO(International Standardization Organization) for each applicatory field.

The sensor network consists of sensor nodes and sink nodes. Data collected by each sensor node within the sensor network is sent to sink nodes and provided to users through outside networks such as the Internet. Sensor nodes are low-cost low-power micro-devices which are composed as sensors for sensing, ADC(Analog to Digital Convert) to convert sensing information into digital signals, process and memory for data processing, battery for power supply, and wireless transceiver for data transmission-reception. USN(Ubiquitous Sensor Network) has developed from early stages of identifying individuals through electronic tagging to simultaneous obtaining of environmental information through added sensing functions to construing networks and controlling other tags with less function via inter-tag communication. USN technology is composed of a network that uses wire/wireless network focused on tags, readers, middleware, application service platforms, etc. As RFID tags are becoming smaller and cheaper, much research on applying object recognition and USN are underway [5 ~ 10].

On the other hand, IP-USN(Internet Protocol-Ubiquitous Sensor Network) is a USN service that provides extensive expandability and insures mobility of sensor nodes, gateway, and sink nodes based on pre-existing IP infrastructure [11]. Numerous studies on IP-USN, at an international level, are conducted as it enables construction of sensor networks in desired locations and provision of various services in connection to Internet infrastructure. Application of IP to sensor networks is to provide minimum network operation and flexible connection to previous wire/wireless networks based on IP to sensor networks operated on identical PHY/MAC. The IP technology applied to sensor networks have been thoroughly verified as being easy to implement between sensor networks and previous PCs and lowering overlapping investment on development costs. If ZigBee was appropriate for small-scale sensor networks, IP-USN is useful in large-scale networks and has the advantage of immediate connection to prior Internet services [12]. By applying Ipv6 standards according to the characteristics of sensor networks, IP-USN effectively interlocked with pre-existing Internet.

2.2. RFID middleware, sensor network platform and service platform

RFID middleware is the system software that collects mass tag data generated from heterogeneous RFID system, filters and summarizes them into significant information, and delivers them to application systems [13]. RFID middleware is used to provide reader interface, filter events, and provide standardized service interface.

Tiny OS, event-based operation system developed by UC Berkeley, SOS of UCLA which allows updates for modules requiring modification during run-time, ICU's ANTS(An evolvable Network of Tiny Sensors) renowned for its evolvability to adapt optimally to surrounding via automatic learning, re-setting, and upgrade, and ETRI's NanoQplus are all sensor network platforms under development. The demand for platforms for integral management of different sensor networks and embrace various technology is a key issue in sensor network platforms. EPC's sensor network platform includes global access networks that support interlock of various sensor network physical infrastructure technologies and global information sharing standard infrastructure of heterogeneous sensor networks. EPC's sensor network platform is also an integral infrastructure of RFID and USN [14].

From the application program development aspect, service platforms provide common services through discovering common necessary service components rather than developing according to each service; they extract common features and services, reuse the extracted features and services, and provide convenience in service development [15, 16]. By providing independent software platform to networks, hardware devices, and wireless networks, service platforms development application programs in a consistent manner and provide software platforms that are easily managed and maintained[17].

3. IP-RFID for port logistics

IP-RFID is the combination of the advantages of RFID and USN technology with minimum IPv6 and port logistics IP-RFID directly manage and control sensors and tags from tracing, monitoring, and bilateral communicating of the current location of containers and interior status of the cargos by attaching sensors to sense the temperature, humidity, impact, opening/closing of doors, etc. and electronic tags with memory, process, and GPS. Embracing IP infrastructure leads to guaranteed extensive expandability and mobility [18].

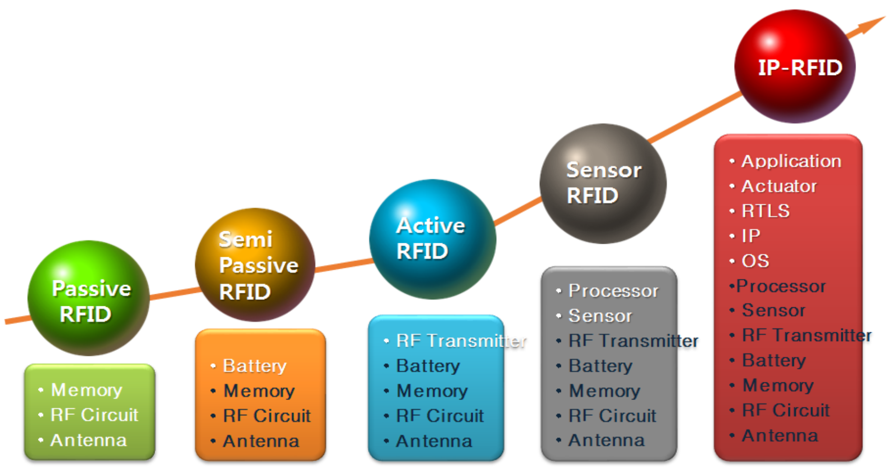

Figure 1. The Functional Differentiations of IP-RFID

Port logistics can be phrased as logistics of cargo through ports, i.e. the logistics of import/export containers. Therefore, the nature of port logistics imply globally situated logistics bases including shipper's factories, container yards, inland container depots, container terminals, etc. and includes land and marine transportation. While the port logistics' agents' demand for global visibility and traceability are on the rise, current RFID systems are limited in realizing these. For example, RFID systems constructed in individual countries cannot be interlocked and so the existence of a single server to share information is required which is unrealistic as this would require RFID systems to be installed in all ports of all countries to actualize global visibility and traceability based on current RFID systems. For example, passing another regional port after losing container cargo would not reveal the event of theft without information sharing between countries. However, with IP-RFID systems, 'What + Where' information is stored in tags and so global visibility and traceability is possible without additional information sharing among countries. From this view, IP-based RFID is necessary in port logistics.

Container-specific tags which identifies the location and status of containers and transmits related information in real-time can be largely divided into all-in-one tags with telecommunication modules for Internet access and detached tags. Tags combined with modules for access to mobile communication networks such as Wi-Fi or CDMA can access communication networks and transmit data without additional AP(access point)s. These tags have IP to access the Internet in forms of USN or M2M. However, detached tags can only access mobile communication networks or Wi-Fi through separate APs, communicate between tags and AP through RF(Radio Frequency), and deliver data transmitted from tags to destinations via Internet. All-in-one IP-RFIDs have the same problems as IP-USN; numerous tags will attempt simultaneous access to Internet in places such as container yards or container terminals which results in difficulty in obtaining the desired information at the desired time, i.e. real-time information, as this would be inefficient, uneconomical, with connect wait and failure. Therefore, this study proposes and implements a detached IP-RFID that detaches Internet communication modules and APs as shown in Figure 2.

Figure 2. The Separated Type of RFID Tag and Access Point

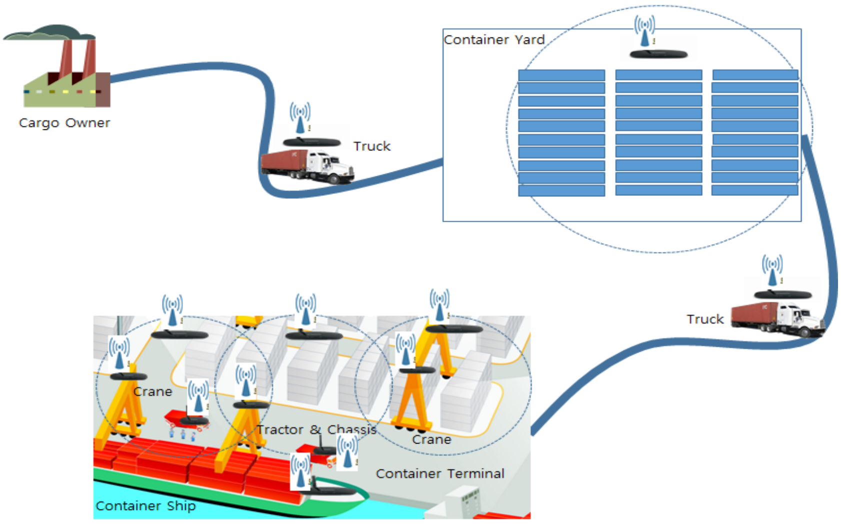

Figure 3. Applied IP-RFID to Port Logistics Process

As shown in Figure 3., the flow of port logistics shows that during transportation, AP transmits data from tags, which are attached to containers in each cell considering the coverage in transportation methods as container trucks or ships or logistics bases such as container yards or terminals, to the destination via Internet. Application at the container terminal is particularly diverse with control over container movement within terminals, tags, and attached devices as tags and APs are both attached to tractors, chassis, transfer cranes, and quay cranes.

4. The smart port logistics service platform

The technological features of the smart port logistics service platform proposed in this study are as follows; first, the data generated from tags are not stored in databases but the queries of clients first stored in databases then uploaded to memories for operations. The stored query, i.e. reception of the information relevant to the particular event monitored by the tag of interest, is analyzed by the service platform and the information of the event is alerted to the client. In such traditional DBMS(Database Management System), data is persistent and queries are transient but in DSMS(Data Stream Management Systems), the queries are persistent and data transient. The client's queries are not expressed in SQL(Structured Query Language) but in XML(eXtendible Mark-up Language). When the client requests the service platform for registration of the query in XML, the service platform conducts parsing and stores in the database. As the received amount of data from multiple tags is immense, they are only processed when certain events occur on tags which the client wishes to monitor and other normal situations are deleted as to save storage space in the database. Second, traditional DBMS and clients communicated via synchronization mode. However, after the client registers the query onto the service platform, the connection with the platform is no longer prolonged. In analyzing collected data from tags, the service platform attempts telecommunication access with the client of interest and operates in non-synchronization mode in the presence of an event to be transmitted to the client. Third, for the service platform to identify the received tag data as the certain event requested by the client, the disc data and consistent memory data is compared instead of searching the disc database; it is an in memory database management system. Services are conducted by uploading data required in the operation of the service platform to the main memory and not the disc.

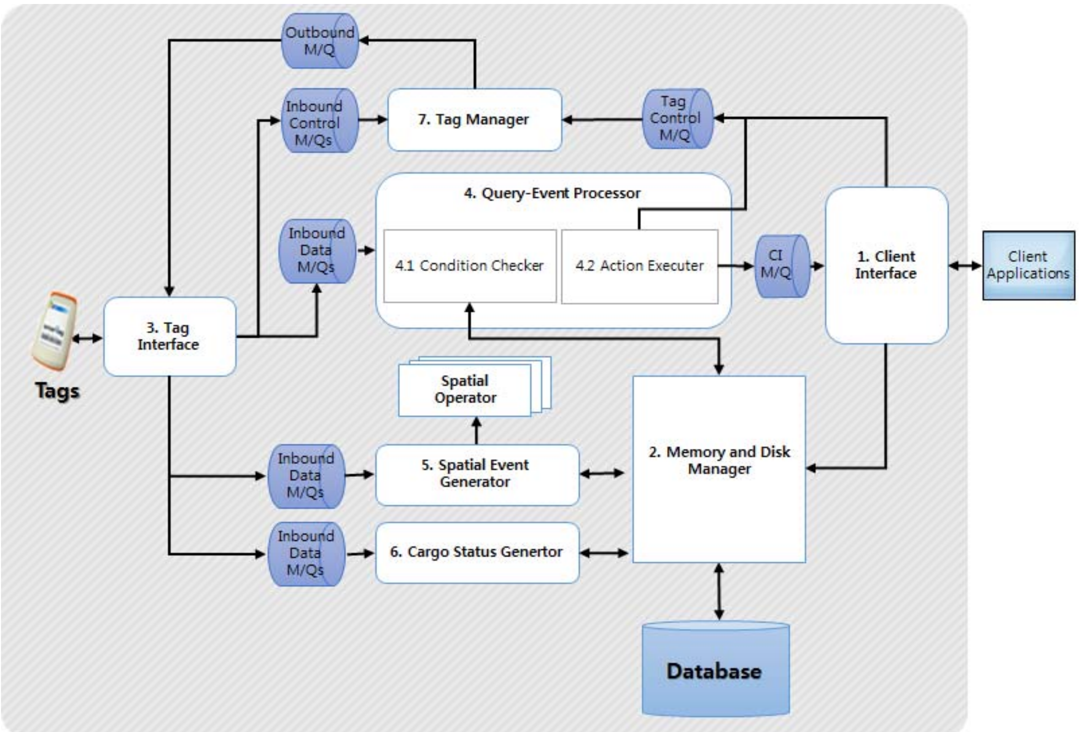

Figure 4. The Architecture of a Smart Port Logistics Service Platform

The Architecture of the smart port logistics service platform proposed in this study is shown in Figure 4.

4.1. Client interface

By distributing open API for client application development, the service platform is available for use in client application development. API includes login, query registration, query modification, query deletion, etc. The client interface is a module that utilizes API to respond to the request of developed clients and provides services by responding to calls of client applications. With logins, login signals are processed by confirming the ID and password of the end user. Query registration is XML for parsing to verify the expressed query and store in the database. As the communication between the service platform and client is non-synchronized communication, management over the IP address, port information, socket information, etc. between the service platform and client is required. Upon registration of the client's query, the service platform creates query ID and then notifies the client. When a certain event occurs and the client needs to be sent the information, the client's socket information is searched and the related information is transmitted. In query deletion, deletion request is made using query ID and socket information and query modification is processed in the order of deletion and re-registration. Also, regarding the client's request for tag control such as adjustment of data transmission period of tags, the request message is parsed, converted into tag-control message used in service platforms, and saved in the module to send the control message to the tag, i.e. message que used by the tag manager. Even tag control of clients such as transmission period modification is processed by the client interface and relevant control information is stored in the service platform.

4.2. Memory & disk data manager

The memory manager maintains the disc data required in comparison of received tag data in the main memory. It is most important that they remain consistent with the data stored in the disc. It also conducts the functions of general DBMS such as storing the query parsed by the client interface in the relevant table. In memory DBMS method is used in service platforms because the inner algorithm that processes queries and tag data is simple and can be performed with few CPU instructions which enables high processing rate of service platforms and increases the economic efficiency of memory. The structure of data stored in the memory is composed in forms of regular linked list and manages the index.

4.3. Tag interface

When the information sensed by tags match a certain event, the sensing data and event type are transmitted to the service platform for processing. The event type includes temperature, humidity, impact, door opening/closing, location, etc., i.e. if an event of change in the temperature or humidity in the container, random impact, opening/closing of the door, change in location occurs, the event type and received data is delivered to the tag interface in the service platform. The tag interface module reviews these received data, identifies the type, and store the data in the message que of the processing module. Also, a tag control packet to control tags is transmitted to the tags.

4.4. Query-event processor

The query-event processor oversees processing of events including temperature, humidity, impact, opening/closing of doors of containers with tags. As multiple clients request various information from a single identical tag, fast search of the data-demanding client is important. In the event of these events, the query-event processor searches the query data stored in the main memory for the client that requested the query. Once the query is being searched, an XML message is composed and saved in the message que of the client interface to send the relevant information to the client that registered the query. If the client requested for action to the event as well as the relevant information, i.e. the registered query includes response to the event, the query-event processor identifies the response stored in the memory, composes a control message to the tag of the action to be taken, and saves it in the tag control message que. The action varies according to the event; for example, if the perceived temperature is high enough to cause an abnormality inside the container, control instructions may include starting the interior fan, fire extinguisher, or other internally installed devices.

4.5. Spatial event generator

For example, if the client registered the query, “notify the time when the container with the number 10 tag arrives at ‘Busan New Port’, the number 10 tag identifies the GPS information attached to the tag and sends its current location coordinate value in a location event type message to the service platform. The tag interface stores the location event data message in the message que used by the spatial event generator which is then read by the spatial event generator. The spatial event generator then performs a spatial algorithm to confirm the received GPS coordinates as the logistics node of interest and transmits the related information to the client by saving it in the message que used by the client interface. The spatial data pre-defines and saves the logistics node of interest in the service platform. The spatial data of the logistics node saves MBR(Minimum Bounding Rectangle) using R*-tree. To identify the received GPS, the spatial event generator searches the received GPS information and R* tree [19] information to conduct spatial operations. The spatial operator consists of identifying the GPS as in, inside the logistics node, ‘out’, outside the logistics node, ‘into’, entering the logistics node, ‘outof’, leaving the logistics node, ‘through’, passing the logistics node, etc. Spatial operation is performed with the MBR closest to the received GPS and the calculation of this distance is the distance between the central point of the four sides of the MBR and the GPS coordinates. Also, the spatial event generator leaves a record of the movement information log of the tag regardless of the client’s query. The module performs the physical roles of the RFID reader in a software manner.

4.6. Cargo status generator

Containers are transported to polar regions, equatorial zones, oceans, and other extreme environments while holding various cargo including hazardous items. Furthermore, unexpected events such as impact, theft, accidents, etc. are faced during the transport. Shippers seek to monitor not only the location of their cargo but also their status. The cargo status generator monitors the temperature, humidity, impact, etc. in real-time through the attached tags and estimates the state of the cargo. Estimation is performed based on fuzzy logic and on certain periods for logging.

4.7. Tag manager

The basic function of the tag manager is to control the tags. The client’s control command and service platform’s action command is made into a control packet to be sent to the tags and saved in the message que used by the tag interface.

The tag attached to the container continues to move hence, the IP address of the mobile tag must be traced for IP communication from the service platform to the tag. Each time the tag’s IP changes, the tag itself transmits to the service platform for management. The tag manager generates a control packet that includes a recipient address, i.e. IP address, and manages the tags.

5. Conclusion

The nature of port logistics requires global location tracking and monitoring of the cargo status. As installing readers around the world is impossible with traditional RFID, a new technology is essential. Also, with USN or IP-USN, the prerequisite is that networks are required and it also implies the problem of inefficient and explosive communication levels in container yards where mass containers and stocked. Therefore, detached IP-RFID technology that separates the internet communication function is suited to port logistics. Tag, which applies IP function to RFID, allows bilateral information exchange and not only can the system control the tags but mounted with memory and process, the tags gain a smart capacity for various functions and roles according to the functional software mounted. Today’s port logistics is at the center of the demands and attention of various stakeholders. After 911, U.S. is enforcing security on all cargo entering its land and new technology is under development.

Direct agents such as cargo owners, shipping liners, trucking companies, container terminals, etc. as well as various stakeholders including port authorities, customs, inspections, governments, etc. are engaged in IP-RFID with personal purposes. Until now, the information demanded by these varying stakeholders will unavailable in real-time. The IP-RFID-based service platform proposed in this study is a service-based information system that can satisfy the different demands of these stakeholders. The spatial event generator to replace physical reader, the cargo status generator to estimate and take action according to the cargo status, and the query-event processor that responds to the different queries and demands of clients are core modules that respond to the potential requests of these stakeholders. For example, if a problem arises in the cargo quality during shipment to a container, there was no means of discovering such abnormality and therefore, no action could be taken. However, in the IP-RFID-based smart port logistics platform, the abnormality in the cargo can be estimated beforehand and the client can be notified for appropriate actions to be taken. If problems in the purchased material or parts are discovered after arrival, not only the particular business but the entire supply chain is delayed. Also, dangers such as fire or explosions of the cargo can be detected in advance enabling appropriate measures to be taken. The risk of theft and loss will decrease, thereby preventing immense loss. In this context, the smart port logistics information system implementing IP-RFID is expected to guarantee global visibility and traceability, core features in modern logistics. Currently, detailed plans of each modules are completed and prototype development is under way. Therefore, it is anticipated that the suitability and validity of the system will soon be investigated through tests.

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