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STUDY OF SMART INVENTORY MANAGEMENT SYSTEM BASED ON THE INTERNET OF THINGS (IOT)

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ABSTRACT

In developing enterprises and the constant demands of the product diversity, traditional Inventory Management model can't achieve that, due to its heavy workload and low efficiency. This paper presents a new type of intelligent Inventory Management System based on the IoT and explains the principles and structure of it. This system has great advantages compared to the traditional mode, and we expect good prospects for its development. Inventory Management is a key area for customer service and cost optimization in any manufacturing setup. As companies turn global and have thousands of components and hundreds of warehouses the inventory becomes a nightmare and a lot of time is spend in tracking inventory and ensuring right shipments. Traditional systems of robotic arms for inventory pick and drop have been based on premises of marking areas of the warehouse and tracking it.

Keywords: Inventory Management System, RFID, Supply Chain Management, IoT, Inventory Optimization

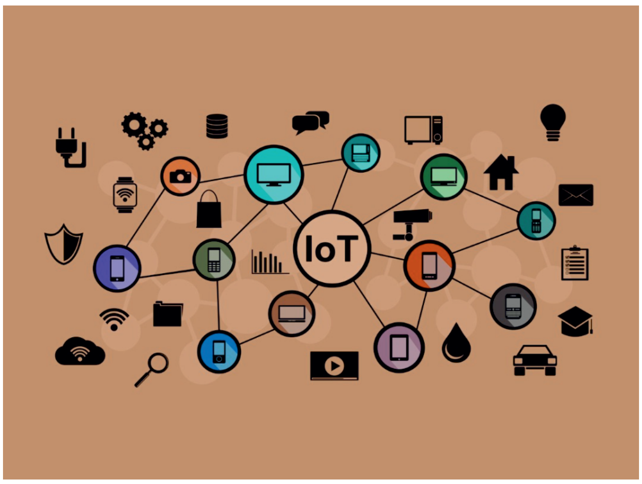
INTRODUCTION

New advent of IoT (Kodali *et al.*, 2016) all this is set to change as inventory objects become more self-aware and self-broadcasting. This paper technically suggests an approach of managing inventory using low energy device and does a statistical case research on two groups of the same organization one before the pilot run where traditional barcode scanners are used to track inventory and other one where the pilot trial RFID (Tesoriero *et al.*, 2009) was used. Statistically the users are much more efficient and accurate and save lot of time and costs in the short run itself. An RFID tag has an ID that is carrying the information about a specific object. It can be attached to any physical surface, including raw materials, finished goods, packages, crates, pallets, etc. In an industrial setting, mainly passive tags are used, i.e. those without their own power supply. Such tags are cheaper but require the power from the reader to be able to transmit data. With RFID and IoT, inventory managers don't need to spend time on manual tracking and reporting. Each item is tracked and the data about it is recorded to a big data warehouse automatically. Automated asset tracking and reporting save up golden hours of working time per month and reduces the probability of human error.

Internet of Things (IoT)

Internet of Things (IoT) model will associate many smart-devices with processing, sensing and actuating the capabilities which are able for connecting to the Internet (refer to figure 1). Combining social networking concepts into the IoT has steer to the Social IoT (SIoT) concept which facilitates people and connected devices to communicate, helping information sharing. However, interoperability, security, and privacy issues are a huge challenge for IoT, but these are also permissive factors to create a faithful and interoperable environment. In fact, without solving these factors, the SIoT model will not gain much popularity and all its potential can be lost. Security factor is prioritized by the deficit of standards specifically designed for devices with limited resources and heterogeneous technologies. Additionally, these devices, due to more vulnerability, serve much more scope for existing cyber threats.

Figure 1: Internet of Things (IoT)



Supply Chain Management (SCM)

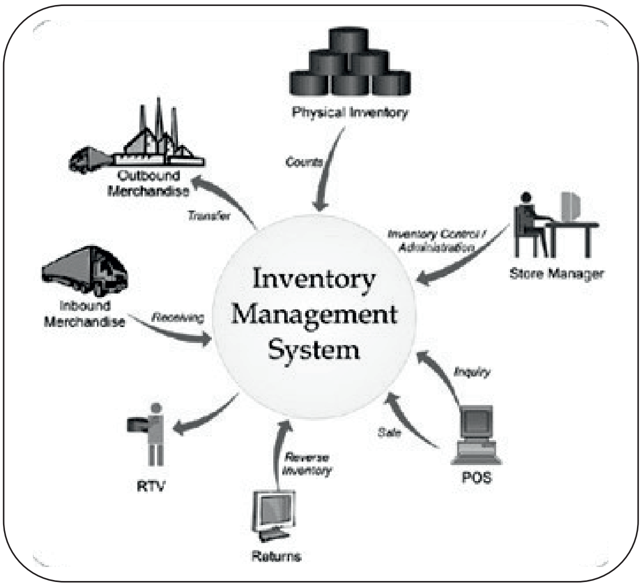
A Supply Chain Management (SCM) (Shen, Fang & Zong, 2009) system is a set of software solutions that maintains and supervise the flow of products, data, and finances as a product or service moves from point of origin to its destination via some intermediaries. Supply chain activities enclose all from product development to logistics, including production and manufacturing, sourcing, transportation, inventory and warehouse management, and shipping. A complete, end-to-end supply chain management system includes the material handling and software packages for all the mediums which work together to create the product, deliver orders, and keep track of information including suppliers, manufacturers, wholesalers, transportation providers, logistics providers, and retailers.

Figure 2: Supply Chain Management

Inventory Management System (IMS)

Inventory management is a complex process, particularly for bigger organizations, but the basics are same indifferent of size or type of the organizations. In inventory management, products are delivered into the acquiring area of a warehouse in the form of raw materials or components and are put into stock areas. In comparison with the bigger organizations with more available physical space, in smaller companies, the products may go directly to the stock area instead of a receiving location, and in case of wholesale distributor, the products may be prepared products rather than raw materials or components. The products are then picked from the stock areas and carried to production facilities where these are made into finished products. The finished products may be restored to stock areas where these are held prior to shipment, or these may be exported directly to consumers. Inventory management uses a variety of data and keeps track of the products as these moves through the process, including lot numbers, serial numbers, cost of products, quantity of products and the dates when these move through the process (refer to figure 3).

Figure 3: Inventory Management System



LITERATURE REVIEW

1. Amount of Inventory

The Stocking of right amount of inventory is vital. If organizations order less, customers will search better options. If organizations order huge, there is a chance that organization will face the problem of overstocking and ultimately forcefully sell at clearance prices to avoid huge loss. The goal of our research paper is to find the right level of inventory to maintain excellent service levels. To achieve this goal, the key is to understand the demand and supply it using lots of data processing.

2. Place of Inventory

Has a need of Specific place where inventory can be stored and distributed, such as a store room or mobile cart. Locations are listed within a hierarchy, with the inventory group at the top level, followed by the inventory primary location, and the levels of inventory storage areas. For example, an inventory group is in Domjur, the inventory primary location is Jalan Complex, Jaladhulogori (Near to Domjur), the first-level storage area is the warehouse building, and the bottom-level storage area is a bin or shelf.

3. Record point of Inventory

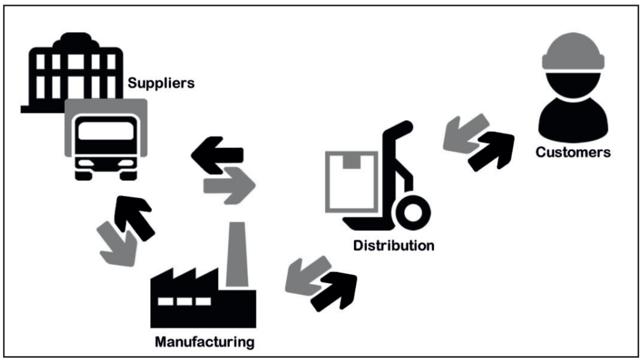
1. Calculate your lead time demand in days.
2. Calculate your safety stock in days.
3. Sum your lead time demand and your safety stock to determine your Reorder Point.

To understand the mathematics behind our reorder point calculator, let's break this formula down. You'll need to know the lead time demand, because that's how long you'll have to wait before new stock arrives - you'll need to have enough to satisfy your customers while you wait! And you'll need to know your safety stock, because that'll protect you against any unexpected occurrences. Add your lead time demand to your safety stock. Once your stock levels hit the total, it's time to place a new order to replenish your supply.

4. Distribution of Inventory

Distributed inventory is a concept where in the goods or inventory which is to be give to the retailers & distributors are divided into multiple shipments, each of which is used to fulfill the inventory requirement. Distributed inventory enables the products or goods to reach out to every customers of the region where the products must be sold (refer to figure 4).

Figure 4: Distribution of Inventory



There are two types of control in distributed inventory systems:

(A) Centralized

In Centralized systems the decision maker at the highest stage decides that, how much inventory should be placed on subsequent stages. It was further suggested that in such type of systems most of the inventory should be allocated to lower stages and few should be kept in higher stages. Inventory should be allowed to keep in higher stages only if carrying cost and load time is very less.

(B) Decentralized

In decentralized systems every stage will take the decision on its own there is no such one centralized decision maker. One problem with such kind of system is that there is lot of approximations and assumptions need to make the inventory level determined at every stage.

5. Method of Stock Control

There are several efficient methods for controlling stock for deciding what, when and how much to order. Apply one or more methods or a mixture of two or more for controlling various types of stock. Depending on different parameters and method of stock controlling that can be classified as follows:

a) **Minimum stock level** - Minimum stock level should be identified and should be re-ordered when stock reaches at that level. This is known as the Re-order Level.

b) **Stock review** - Regular stock reviews should be conducted. At every review an order should be placed to return stocks to a prearranged level.

c) **Just in Time (JIT)** - This method aims to cut down costs by reducing stock to a minimum. Items are dispatched when these are required and used quickly. For avoiding risk of running out of stock suppliers should deliver on demand. This method can be used with other processes to filter the stock control system.

d) **Re-order Lead Time** – This method allows for the time between placing an order and receiving it.

e) **Economic Order Quantity (EOQ)** – It is a standard formula which is used to arrive at a balance between holding too much or too little stock. It is quite a complicated calculation, but to make it simple use stock control software.

f) **Batch Control** – This method manages the production of products in batches. You need to make sure that you have the right number of components to cover your needs until the next batch. If your needs are predictable, you may order a fixed quantity of stock every time you place an order, or order at a fixed interval - say every week or month. In effect, you're placing a standing order, so you need to keep the quantities and prices under review.

g) **First In, First Out (FIFO)** - a system to ensure that perishable stock is used efficiently so that it doesn't deteriorate. Stock is identified by date received and moves on through each stage of production in strict order.

RESEARCH METHODOLOGY

1. Inventory Optimization

As shoppers hustle to ship or bring back items that don't fit or they don't like, there's an opportunity for retailers to move that inventory quickly to another loyal customer. But without the ability to see returns or exchanges in real time, that inventory becomes a burden on the bottom line. After employees and "store estate" (physical and online premises) inventory is arguably the most valuable resource a retailer has. Without it, the retailer cannot trade. Now in those days, inventory is more valuable than ever, but it must be in the right place at the right time — or the business suffers. The connectivity and real-time analytics inherent in IoT could be the game changer for retailers' inventory woes.

a) Tools for Inventory Optimization

RFID chips can be placed on clothing, or even inside it, to give each garment an individual ID. RFID chips are cost effective and don't require any power source (battery or electricity); companion technology (RFID readers) enables fast and accurate locating. Along with other IoT-enabled technology — a combination of store-shelf sensors, smart displays, digital price tags and high-resolution cameras — retailers can see what is where. From the store shelf to the back stockroom, central warehouses and other stores, they can link these sets of inventory data for full visibility.

b) Material Requirement Planning

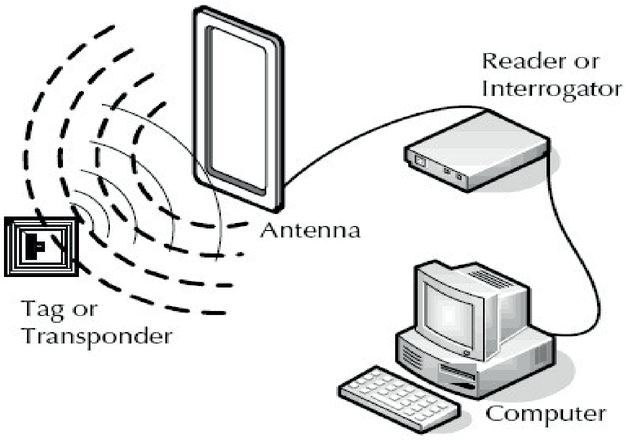
Material requirements planning (MRP) is a system for calculating the materials and components needed to manufacture a product. It consists of three primary steps: taking inventory of the materials and components on hand, identifying which additional ones are needed and then scheduling their production or purchase. MRP is one of the most widely used systems for harnessing computer power to automate the manufacturing process.

2. RFID System

Radio-Frequency Identification (RFID) is the use of radio waves to read and capture information stored on a tag attached to an object. A tag can be read from up to several feet away and does not need to be in within direct line-of-sight of the reader to be tracked. The Warehouse inventory management system is one of the applications of RFID technology, because RFID can uniquely identify products or goods attached with tags. The RFID reader em-18 used to read 125 kHz tags. The RFID reader operates at a voltage of 5V. The Reader has two fundamental objectives: initially reader to transmit a carrier signal and the subsequent is to receive a response from any tags in the proximity of the reader. The RFID reader emits a short-range radio signal which is picked by a RFID tag and the tag is triggered on.

A RFID system is made up of two parts: a tag or label and a reader. RFID tags or labels are embedded with a transmitter and a receiver. The RFID component on the tags has two parts: a microchip that stores and processes information, and an antenna to receive and transmit a signal. The tag contains the specific serial number for one specific object. To read the information encoded on a tag, a two-way radio transmitter-receiver called an interrogator or reader emits a signal to the tag using an antenna. The tag responds with the information written in its memory bank. The interrogator will then transmit the read results to an RFID computer program. There are two types of RFID tags: passive and battery powered. A passive RFID tag will use the interrogator's radio wave energy to relay its stored information back to the interrogator. A batter powered RFID tag is embedded with a small battery that powers the relay of information (see figure 5 below).

Figure 5: Working function of RFID



In a retail setting, RFID tags may be attached to articles of clothing. When an inventory associate uses a handheld RFID reader to scan a shelf of jeans, the associate can differentiate between two pairs of identical jeans that based upon the information stored on the RFID tag. Each pair will have its own serial number. With one pass of the handheld RFID reader, the associate can not only find a specific pair, but they can tell how many of each pair are on the shelf and which pairs need to be replaced. The associate can learn all this information without having to scan each individual item. RFID systems (Huynh *et al.*, 2014) feature three main components: RFID tags, RFID antennas and RFID readers.

Figure 6: Components of RFID

a) RFID tags

An RFID tag has an ID carrying the information about a specific object. It can be attached to any physical surface, including raw materials, finished goods, packages, crates, pallets, etc. In an industrial setting, mainly passive tags are used, i.e. those without their own power supply. Such tags are cheaper but require the power from the reader to be able to transmit data.

b) RFID antennas

An RFID antenna (Kumar & Roy, 2014) catches the waves from the reader to supply energy for tags' operation and relays the radio signal from the tags to the readers.

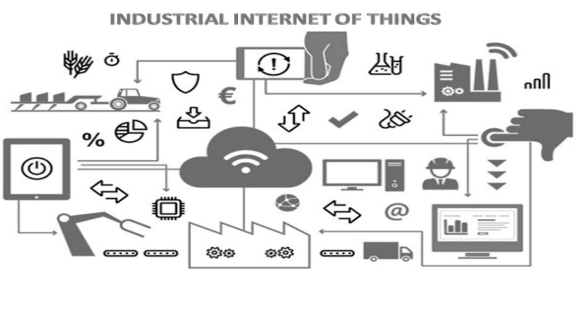
c) RFID readers

An RFID reader (Kumar & Roy, 2014), which can be either fixed or handheld, uses radio waves to write to and read from the tags. It can read from the number of tags over distance. The reader catches the IDs that are written in tags' memory banks and transmits them to the cloud, together with the data about the readers' locations and the time of readings.

d) IIoT

The role of IIoT in inventory management boils down to turning the data fetched by RFID readers into meaningful insights about inventory items' location, statuses, movements, etc., and giving users a corresponding output. For example, based on the data about the inventory quantity and location, machine learning – a component of IoT-based inventory management solution architecture (Lin, 2012; Gubbi *et al.*, 2013)– can forecast the amount of raw materials needed for the upcoming production cycle. The output of IoT system provides can have various forms: it can send an alert to a user if any individual inventory item is lost, notify the need to replenish materials, etc. Moreover, inventory management solutions based on Industrial IoT can be integrated with other systems, say, ERP – and share data with other enterprise's departments. For instance, since inventory value can be a significant portion of a company's assets, inventory data is crucial for an accounting department to ensure that a company's annual reports and tax returns are accurate (see below figure 7).

Figure 7: Applications of RFID



3. Advantages of IoT based System

IoT-based inventory management lays a solid foundation for the digitalization of the manufacturing ecosystems and offers both process and business benefits, including:

a) Automation of inventory tracking and reporting

With RFID and IIoT, inventory managers don't need to spend time on manual tracking and reporting. Each item is tracked and the data about it is recorded to a big data warehouse automatically. Automated asset tracking and reporting save up to 18 hours of working time per month and reduces the probability of human error.

b) Constant visibility into the inventory items' quantity, location and movements

An IoT-based inventory management solution gives manufacturers precise visibility into the flow of raw materials and components, work-in-progress and finished goods by providing real-time updates about the status, location, and movement of the items, so that inventory managers see when an individual inventory item enters or leaves a location.

c) Inventory optimization

The better inventory managers know their stock, the more likely they are to have the right items in the right place at the right time. With the real-time data about the quantity and the location of the inventory items, manufacturers can lower the amount of inventory on hand while meeting the needs of the customers at the end of the supply chain.

d) Identifying bottlenecks in the operations

With the real-time data about the location and the quantity of the inventory items, manufacturers can reveal bottlenecks in the manufacturing process and pinpoint machines with lower utilization rates. For instance, if part of the inventory tends to pile up in front of a machine, a manufacturer assumes that the machine is underutilized and needs to be seen to.

e) Lead time optimization

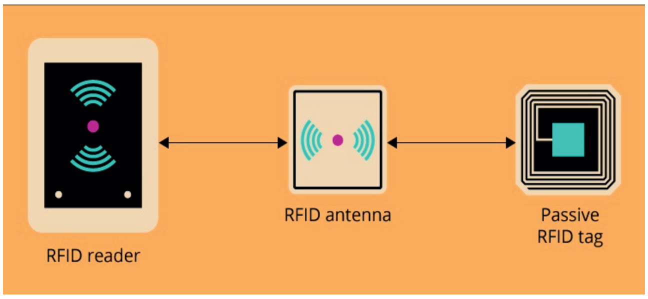
By providing inventory managers with the data about the amount of available inventory and machine learning-driven demand forecasts, solutions based on IIoT allow manufacturers to reduce lead times. Here is an example: a RFID-based inventory management solution allowed Zara to take a garment from design through the manufacturing process to a smart warehouse in just 10 days.

4. Inventory Management System based on IIoT and RFID

Inventory management based on IIoT and RFID

(Ziegler, Graube & Urbas, 2012) works, let's consider an example. Say, among other pharmaceutical equipment, an enterprise produces single-punch tablet presses. The enterprise owns two geographically dispersed factories: one – to produce press components, the other – to assemble the final unit (Huynh *et al.*, 2014). At the start of the production cycle, the components for, say, die lower punches, get passive RFID tags. Each tag is granted a unique identification number that contains data about every part. The list of tags' IDs (Ziegler, Graube & Urbas, 2012) is saved to a big data warehouse. During the manufacturing process, as the tagged components move from station to station and from shop to shop, the RFID readers (Want, 2006) scan the tags and relay the IDs, the time of the readings, and the data about the location of the readers to the cloud (refer to figure 8).

Figure 8: Data Exchanging Procedure of RFID



The cloud analyzes the incoming data and identifies the locations and the statuses of the components. If any of them is missing, the cloud pinpoints the missing part, sends an alert to a solution user and sets the status of the item in the inventory management solution to 'missing'. As soon as the location of the component is identified, its status is set back to 'in production'. When the production of the die lower punches is finished, they are shipped to the other facility for assembling. They are packed in packages and crates, put on pallets and placed in vehicles, the vehicles are scanned with a handheld RFID (Wang, 2012) reader before they depart. The employees at the assembly affiliate see that the parts have left the production affiliate. Once the parts arrive at the assembly facility, the vehicles are scanned with handheld readers one more time to make sure no items are lost. As soon as the single-punch tablet presses are assembled, each press receives another tag (the tags from press components can be either kept or removed, depending on the cost-effectiveness of the required operations). As the presses move from department to department, say, from assembly to quality check, the readers installed in the doorways scan the tags attached to the presses to relay the data to the cloud and identify presses' precise location. The presses are tracked all the way till the moment they are shipped to a warehouse. In the warehouse, the reader scans the tags and in case the cloud detects a missing unit, it sends an alert to an operator. If the IoT-based inventory management solution doesn't report any missing units, the pallets are fork lifted and unloaded. As a result, manufacturers track the inventory from the day the individual components were manufactured to the day the assembled unit arrives at a warehouse and then departs from it to reach end-customers.

5. Outcome of the System

An IoT-based inventory management and asset tracking solution offers constant visibility into the inventory by providing real-time information fetched by RFID tags. It helps to track the precise location of raw materials, work-in-progress and finished goods. As a result, manufacturers can balance the amount of on-hand inventory, increase the utilization of machines, reduce lead time, and thus, avoid hidden costs bound to the less effective manual methods.

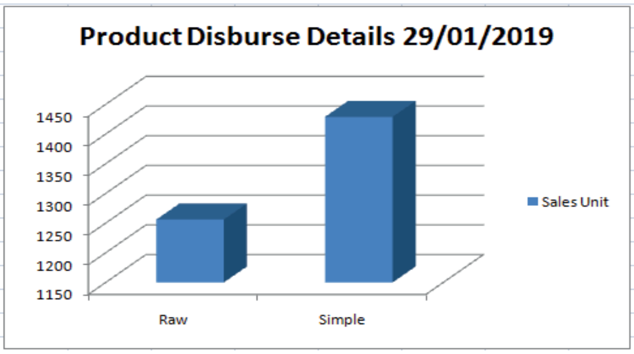
RESULTS AND DISCUSSION

Resultant value stored in the last access details and updated details also available in table format. This table also gives available details of product type as raw or simple. Raw and wet materials are needed to be disbursed soon with comparing to dry products. The table 1 & figure 9 below describes date wise product details. This system also provides date wise stock details.

Table 1: Data Processing Details of Stock Table

Sl No	ID Number	Product Type	Stock Room No	Last Date Operated
1	PR001	Raw	SR023	24/01/2019
2	PR002	Raw	SR024	25/12/2018
3	PR003	Raw	SR025	17/03/2019
4	PR004	Raw	SR023	21/4/2018
5	PR005	Simple	SR025	17/11/2018
6	PN005	Simple	SR025	20/02/2019
7	PN006	Simple	SR023	17/09/2019
8	PN007	Simple	SR025	4/8/2019
9	PN008	Simple	SR023	11/3/2019

Figure 9: Product Disburse details of a Day

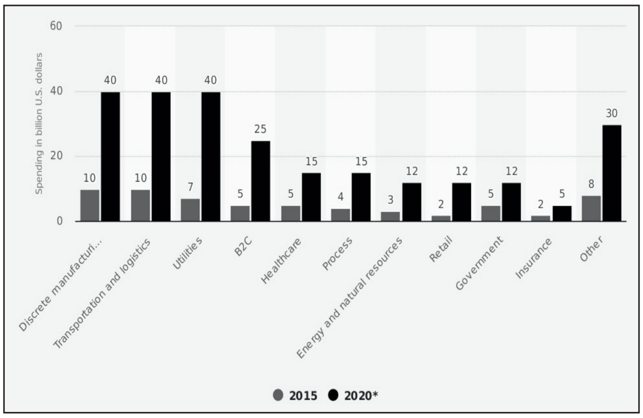


Following benefits, we can get from this IoT system in which all consideration required to manage resources.

i. Managing Production:

System can simulate the whole process of production enterprises and make production smart management function through the application of IoT (Wang, 2012) technology (refer to figure 10). Production management module include functions of product labeling, product processing and finished product checking; The production plan management module draw up the plan according to receive orders from system; Order management module includes viewing order information and order processing; Production management module of the system can manage product categories of system production; Warehouse management (Huynh *et al.*, 2014) includes inventory management and out of storage management function, the former monitoring products in stock information, the latter shipment handling according to processed orders; Customer management module maintain information of customer; System settings consists of a serial port settings and information settings and set up the software running parameters.

Figure 10: Worldwide Use of IoT in Different Projects



i. Smart Distribution Process:

In simulated distribution link, distribution center according to the supermarket order generate stock out and distribution list, the former is given Warehouse and later is given transport sector. After out of storage the system automatically updated inventory information; After the completion of out of storage, the goods are packing after passing sorting operations; In the packing, a certain number of finished goods package boxes, and labeling in each box. In the transport links, box as a unit will be managed. Transport department is shipment preparation after getting distribution list, first it distribute vehicles, drivers for distribution list and improve the distribution list information; At the same time, before loading the number of box is carried in a pallet, RFID electronic label is affixed to each pallet and pallet ID associated with the vehicle ID. Form of the only vehicles and the only driver with the corresponding pallet are monitored eventually. Smart shelves in the warehouse will real-time monitor the inventory information updated, if the inventory number is less than a certain range, distribution center generate produce replenishment order to inform the production enterprise for production and processing activities. Smart shelves will realize automatic quick inventory physical count. And inform the EPCIS (EPC Information Services) server out of storage, warehousing and inventory of commodity information. This system complete intelligent inventory management function by adopting the smart shelves.

ii. Process of Intelligence Transportation:

Platform can simulate the whole process of transportation and realize intelligent transportation management functions through the application of IOT technology. In road link (Ibrahim & Ibrahim, 2010), the drivers of transportation get distribution list and complete the preparation activities to automatic complete the vehicle and the driver matching through the RFID technology, and start a series of executable program of vehicle like opening the GPS system automatically, show distribution tasks and route, etc. In road, vehicle real-time send in road information to the data center including vehicle speed and position information, etc. When abnormal situation has happened, such as speeding, deviating from the transport routes, system gives an alarm, starts vehicle anti-theft system, and report vehicle position information to the data center server.

CONCLUSION

This paper built a supply chain simulation platform system based on IOT technology, analyzed the application of key technology in the system, and designed smart shelves subsystem, smart shopping cart subsystem and so on. The operation process is simulated according to the particularity of the supply chain enterprise. The system can provide a full range of search service for customers through the WEB service and realize the visualization management of the whole process of mobile commerce so the user can trace the whole process of goods for safety and achieve more efficient supply chain management. Following chart shows the acceptance of IoT in different future projects in respect of U.S. billion dollars.

The developed Warehouse inventory management system is very efficient, it can perform dynamic data updating and Real Time search operations from the database with the help of a web server. Thus, the implementation of RFID System of this proposed methodology is not bounded to prototype or laboratory setup but can also work efficiently in Real world application. The total implementation cost of the developed warehouse inventory management system is very low compared with the present existing models in the marketplace. With the implementation of user-friendly user interface, the users can easily spot the tracked product in the Warehouse without much effort. In future, this innovation can be used in several areas in different applications and many enhancements can be done so that it can be made available to all the sectors.

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