Interfacing internet of things technologies of RFID, XMPP and Twitter to reduce inaccuracies in inventory management .

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Abstract: A critical issue in inventory management is having accurate and timely information on stock levels. Stock-out often occurs in the retail industry due to human errors, theft, or product counterfeiting. Counterfeit products, expired products, and misplacement of products pose a challenge in inventory management. Therefore, advantage should be taken of technologies that can reduce the impact of counterfeits, expired products, and misplaced products. One such group of technologies is the Internet of Things (IoT). This study develops an architecture that uses IoT technologies as enablers for detecting expired products, counterfeit products, stock levels, and misplaced products for inventory management in retail enterprises. The proposed model uses extensible messaging presence protocol (XMPP), radio frequency identification (RFID) to provide a communication mechanism between the inventory manager, inventory processes and the users. Twitter is central to providing feedback to the relevant user on the state of the inventory, while radio RFID technology is used in detecting the products. The Twitter service is provided via Beachcomber.

General Terms
Design

Keywords: IoT, XMPP , RFID, inventory control, retail enterprises, Beachcomber, Twitter, Arduino

1 Introduction

Inventory refers to the stock necessary to do business and the management of such stock. Inventory management is vital in retail for effective and efficient supply chain processes. These processes include forecasting, stock replenishment, ordering, and effective utilization of stock information. Inventory accuracy is a key problem if overlooked. Inventory systems need to have accurate inventory records of stock on hand and stock to be ordered, but most small retailers find it difficult to know how many products they have in the store. The actual inventories or perpetual inventory (PI) in the store and inventory records are not always up to date. PI is the keeping of book inventory in parallel with the stock on hand within specified time intervals. Stock on hand and book inventory is compared to check the inventory to be ordered and inventory on hand.

Inventory management systems are able to calculate PI based on the stock that is present (on hand), but this information is not always accurate and thus the ordering process is based on the information which is not correct. To reduce these errors would require more human labour in the form of physical counts, resulting in increased labour cost. Yet the accuracy of the counts can still not be guaranteed. The basic PI inaccuracy is either overstated or understated. An overstated PI occurs when an inventory system shows more inventory than the actual stock available in the store. An understated PI happens when the system shows fewer items than the actual levels. These items are called 'hidden inventory'. These PI inaccuracies result in too much, or too little stock being ordered. The result is excess cost, reduced profit, and poor inventory control (Goyal, 2009).

In addition to stock level management are the problems of counterfeit products, expired products and misplaced products on the shelves. This research proposes the adoption of internet of things (IoT) technologies in the management of inventory. The IoT in 2020: roadmap for the future defines the IoT as 'things having identities and virtual personalities, operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental and user contexts" (The IoT in 2020, 2012). This paper is about an architecture to enhance inventory management through the integration of IoT technologies. These IoT technologies include Twitter, radio frequency identification (RFID) and the extensible messaging presence protocol (XMPP). The RFID is for sensing the items in inventory. Communication between RFID tagged objects and humans using a number of protocols and applications such as XMPP and Twitter is enabled via Beachcomber in this research. Beachcomber is a proprietary software.

This paper is organised as follows: The next section is the methodology. Section 3 is on inventory control concepts. Section 4 is on IoT in inventory control. Section 5 is on the role of social networks. Section 6 is on the inventory management architecture. Section 7 is on the benefits of IoT in inventory management. Section 8 is the conclusion.

2 Methodology

The methodology is software and hardware development in a laboratory set-up.

2.1 Aims and objectives

The aim of this study is to come up with an enhanced inventory management system that exploits IoT technologies. The result will promote the efficient use of information as provided by IoT technologies in support of the inventory processes.

The research question is:

"How can we integrate IoT technologies into an inventory management system in order to promote its efficient management .

The objectives of the research were to:

- Review literature on inventory management and IoT technologies
- Design and implement the architecture of a system that integrates IoT technologies in the enhancement of inventory management

2.2 Process

This study is on the design and implementation of an enhanced inventory management system which enhances information utilization in the retail environment using the IoT technologies The RFID readers and tags are used to uniquely identify products in inventory. The system also uses Beachcomber, which is a proprietary platform designed to enable communication between things (items) via XMPP, HTTP and QR Codes to humans via e-mail and Twitter. In this case, Beachcomber will send messages via Twitter to the intended user/inventory manager. The main objective is to allow easy access, mobility and to access updates on inventory anywhere, anytime and thus the effective use of information for inventory processes.

3 Inventory control

Inventory is the most visible and tangible aspect in a business. It refers to stocks or material to do business. The figure below illustrates the inventory processes.

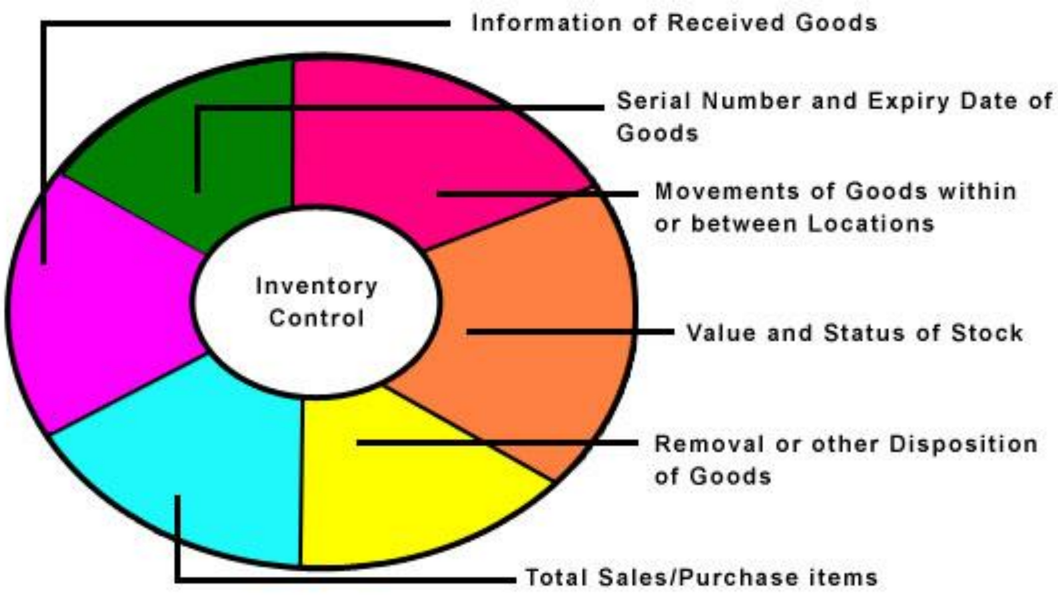

Figure 1: Inventory Control in a Retail Industry (source: inventorymanagement.com)

The inventory control processes in retail industry entails, information on received goods/ stock, which involves the counting of stock and validations and issuing of invoices. Serial number and expiry dates, involves the checking of damaged and expired products using their serial numbers. The movements of goods within or between locations involves the packing of stock from warehouse to the shelves for consumers. It may also involve the shipping of goods to other destinations. Value and status of stock is about stock replenishment on shelves, products that running low and order request that have been sent to the suppliers. The removal and disposition of goods involves the unwanted goods from the inventory. It may be that the product is no longer good for consumption or it is damaged. The total sales involves the total amount of product sold on that day. It also determines the growth or the loss in the business. After sales analysis, the stock to be ordered can be identified.

Poor inventory management is costly and it can lead to profit loss in the business.
The following are types of inventory control systems:

- Visual Control - The inventory is examined visually. This type of inventory control is mostly used in small businesses for slow moving stock.
- Tickler control – Products are physically counted on a daily basis in small portions or by segments.
- Click sheet control – The item is recorded immediately as it is taken or used..
- Stub control – A part of the price ticket of the item sold is retained. The inventory manager uses the stub to record all items sold and which ones to order.
- Point-of-sale terminals – Information on each product is transmitted as it is sold. The inventory manager receives printouts on a regular basis for review and decision making.
- Offline point-of-sale – Information is transmitted directly to the supplier system, the supplier uses this information to ship stock to the buyer (Floyd 2009)

4 Components of IoT and the role of RFID in inventory control

The IoT is the worldwide interconnections of objects/things, which are uniquely distinguishable, by means of established communication protocols. These objects communicate among each other using intelligent communicating mechanisms such as RFID tags, sensors, and actuators. RFID is defined as wireless sensing technology using electromagnetic signals. The RFID technologies have been around for years now, and have been applied in many applications i.e., logistics, warehouses in retail industry, farm animals tracking, tollgates etc. The IoT connects almost any object to the internet, exchanges information about the object, and communicates using the technologies like RFIDs, infrared sensors, global positioning systems (GPS), and laser scanners.

IoT tools intelligently enable locating, identifying, tracking, and monitoring of objects over the internet. IoT is a three layer system. These layers are (1) the sensing layer, (2) the network layer, and (3) the application layer. The sensing layer consists of code labels and readers, which can be RFID tags and readers, camera, GPS, sensors, machine-to-machine terminals and sensor network gateways. The network layer is the integration of communication networks and the internet; it supports the intelligent processing of massive amounts of information, incorporates network management, transports data, connects cloud computing platforms, and supports expert systems. The network layer is the infrastructure that can assist the IoT to become a worldwide service. The application layer is known as the input and output control terminal. It is a set of intelligent application solutions that combine the IoT technology and industry field technology. The main responsibility of the application layer is the social sharing of information and ensuring the security of information (Manli, 2010).

4. The role of social networks

Social networks support human needs. For example, using these networks, users post their statuses on Facebook and Twitter. Social networks play an important role in personal relationships. It makes relationships more lively and manageable over distance through instant messaging (Kranz, 2010). Groups, gatherings, and discussions can be formed easily over the network. Social networking is not only limited to personal relationships. It has even moved to the enterprise, namely, Enterprise 2.0. Social networks are also used for business purposes such as in marketing, brand testing, and business collaboration. The emergence of the IoT addresses another human need as it allows status notifications on objects they own without the need for human intervention in doing so. For example, a car can tweet when it is due for a service and a washing machine can tweet when it is done with the washing cycle.

In IoT processes, networked objects exchange data among themselves to perform their tasks through sensors and actuators. However, the information exchanged in the IoT is not visible to humans and thus there is a missing connection between human and their objects (Mathaba, 2011 and Kranz, 2010). As a result this study propose the use of proprietary software called Beachcomber to enable mobile communication between unsupervised RFID-enabled inventory processes and inventory managers.

Figure 2 illustrates Beachcomber and its protocols. Beachcomber is a platform developed to enable easy communication between things and humans. It enables things to communicate using a number of protocols such as XMPP, HTTP, and QR codes. Beachcomber also enables humans to communicate using applications/protocols such as email, XMPP, and Twitter. Beachcomber links things to their human owners (Butgereit 2011). This paper proposes to take advantage of Beachcomber protocols, i.e., Twitter and XMPP to enhance the communication process on inventory management. Beachcomber can receive RFID tag information that has been transmitted using the XMPP protocol, and convert that information into a readable format for the user. When using Beachcomber, communication can either be synchronous or asynchronous.

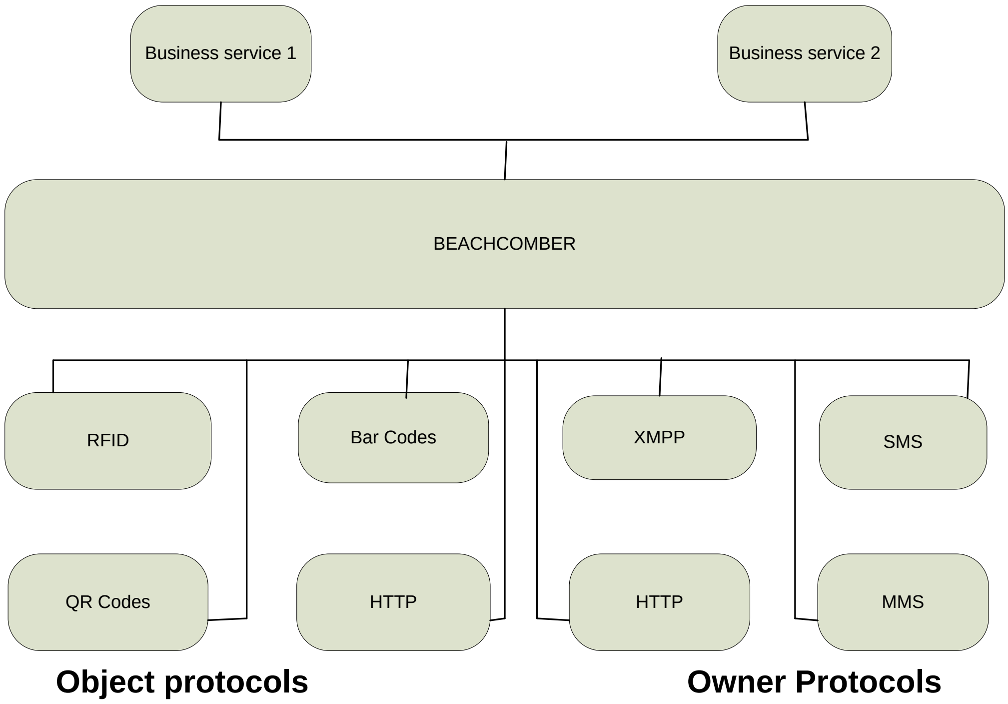

Figure 2 . Beachcomber Model (source: Butgereit, 2011)

5. The inventory management architecture

In this inventory management architecture, the RFID-enabled reader device reads RFID-tagged products and sends the product ID and timestamp messages via XMPP over the internet to the XMPP server. The local server will then send messages to Beachcomber. The Beachcomber in turn will then send messages to Twitter via XMPP. All XMPP communications with the local server must traverse the XMPP server. The timestamp is the number of milliseconds that have elapsed since the exact time when the product was read.

Figure 3 illustrates the envisaged architecture which includes RFID, XMPP, Twitter, Arduino and Beachcomber. When completely implemented, the system keeps the retailer informed on inventory process activities using Twitter . The endpoint device is made up of three boards – the RFID reader, the Arduino and the ethernet device. The reader device is an RFID tag reader and an XMPP client. It reads RFID tags on products and sends information as XMPP messages to the local server. The device sends messages through the internet to the XMPP server which forwards the messages to the local server. The local server does not act as an XMPP server. Therefore all XMPP communications with the local server must transverse the XMPP server. The information from the tags is the product ID and the time stamp.

In the system the RFID-enabled shelf shown in Figure 4 rotates for the RFID-reader to access the product information. Products are placed on the shelf according to product zones, e.g, a sugar zone for sugar, a milk zone for milk, etc. Each product zone has zone start and zone end tags. You cannot read the product ID before you can come across the product zone. In the local server, all the product information messages are collected and sorted according to the timestamp. The database holds the intelligence of what a particular tag means. For example, zone ID 000-00-AF-11 could be an identifier for the bread zone. The RFID-reader knows the zone it is in at any point in time from communicating with the database in the local server which holds information on the identities of the product zone delimiters. It sends the zone ID and timestamp to the database and advises it to retrieve the zone name for the zone ID. The database returns zone ID, compares if the product zone ID of the product is the same as the current zone ID. If not then the product is misplaced.

Example of the data structures for the zones and products are as follows:

ZONES
zoneID: 0000-00-AF-011 [RFID tag of the zone delimiter]
zone Name : Bread

PRODUCTS
ProductID**:** 000-00-AR-BB-001 [RFID of the product]
zoneID**:** 0000-00-AF-011
ProductName**:** Bread

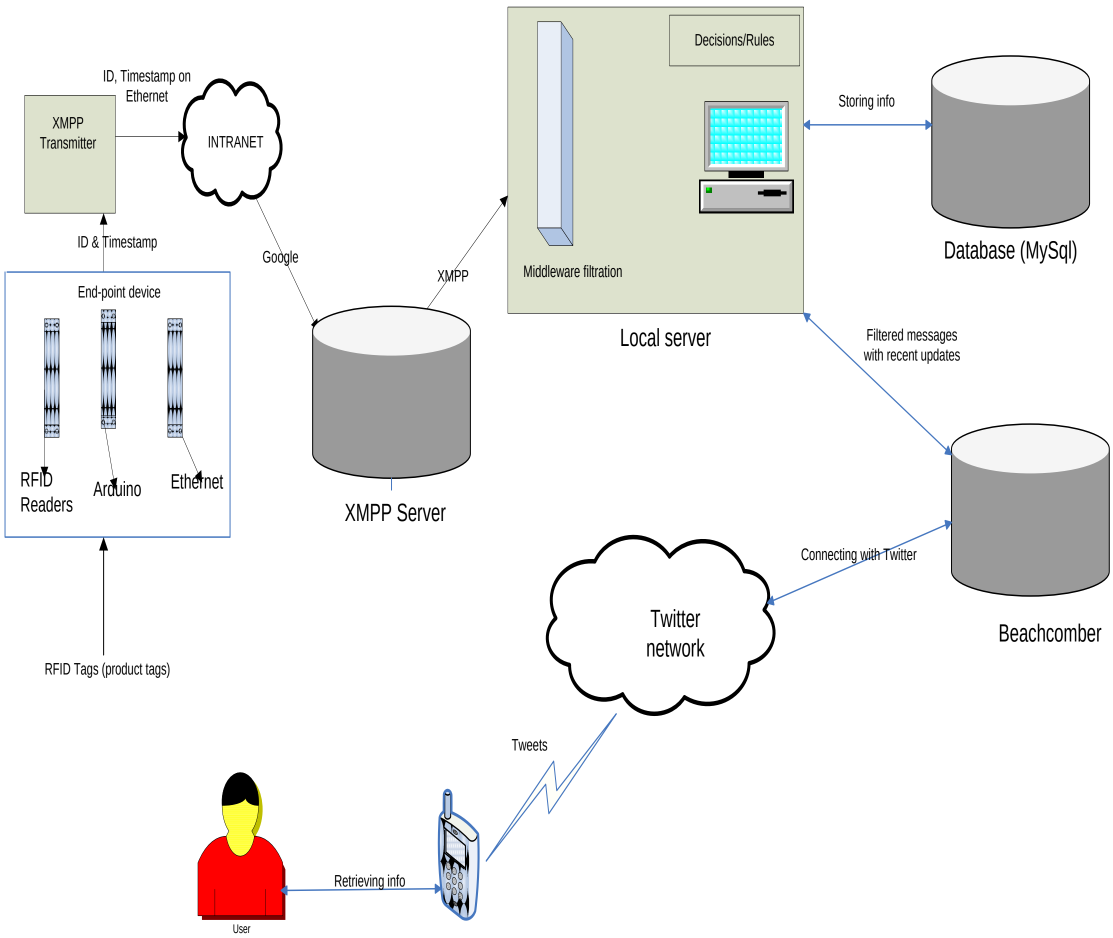

Figure 3. XMPP and RFID in Inventory Control

The following describes the system components in more detail.

The Arduino in the end-point device scans the RFID-tagged products on the product shelves. The product information, that is, the product ID and timestamp is sent via XMPP protocol to the server that hosts the decision support system. The decision support system receives the product information in the form of XMPP messages. It forwards these XMPP messages to Beachcomber. Beachcomber forwards the XMPP messages to Twitter as “tweets”.

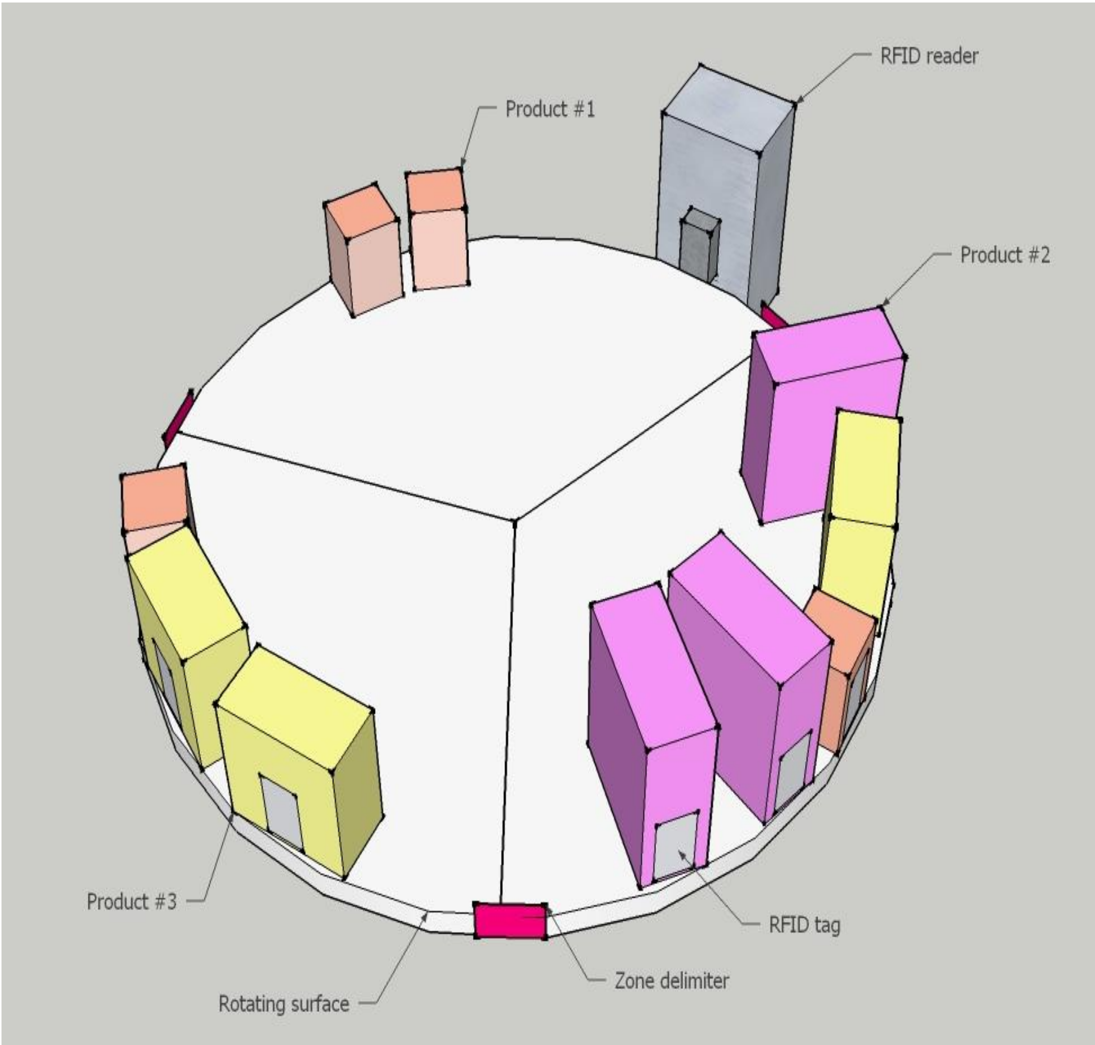

Figure 4. RFID-enabled shelf

The following pseudo code describes the process in more detail:

```
While (there are still zones to scan)
    {Get zone_ID and set as current Current_zone};
        While (the next element IS NOT a zone delimiter)
          {Do get product_zone_ID};
```

```
// checking for expired products first

Get product_expiry_ date;

   If (product_expiry_date < now)
    Then
      {send product_expiry_notification};
    End If

// if not expired

Else
      if
            (Product_zone is same as current_zone);
    Then
             {Product is on correct shelf ;
             Increment_product_count};

Else
          {Product misplaced;
          Send notification;
          Stock level is low};

End if


// counting level of stock

For all Product zones:
Loop
      If (product= inzone_count + outOfZone_Count);
         If (product_ total<= threshold);
Then
       {Send low stock notification};
End Loop
```

The following can be said about the current technology:

- ❖ RFID technology sometimes experience poor read rates and poor accuracy (Upfold, 2010). As a result the study experiment was conducted in a small store room to simulate the retail environment.
- ❖ In the smart shelf for inventory control, the products need to be scanned first and the information stored in the database. In the laboratory experimental system, the shelf simulation consists of a round wooden table top mounted with an RFID reader and zone delimiters. RFID tags are used as zone delimiters and mounted onto the table to categorise products and the RFID reader scans tags mounted onto products.
- ❖ The reader rotates at certain intervals to read the inventory status. When the table rotates, the RFID reader detects all the delimiter and products in sequence. The system then retrieves information from the database and sorts the products according to their zones. If any products are found in a wrong zone, an ‘event’ is trigged. The system then sends a message to Twitter. A similar event is triggered when the products level on a shelf has reduced to a preset level at which more products need to be ordered. The user can view the updates on Twitter.

6. IoT in the enterprise and its benefits

The maintenance of data on required stock and disposal of unwanted items is important when determining the stock to be ordered. The first large scale application in enterprises of IoT was to replace the bar codes in enterprises. Smart systems that have capabilities of self configuring, self monitoring, and self recovering are useful to large retailers when it comes to the management of large and rapid growing processes and devices (Haller, 2010) and (Haller, 2006).

The main barrier is the cost of this technology, lack of standards, and poor read rates on metal products, liquid products, and security concerns in the retail sector (Upfold, 2010)]. However in RFID-enabled inventory control optimisation, Wal-Mart RFID-enabled stores were efficient in reducing out of stocks by 63%. The understated PI inaccuracy was reduced to 13% (Dane, 2006). This shows that RFID technologies can play a major role in retail enterprises.

The pros of adopting RFID-enabled technologies in enterprises are as follows:

- **Automatic non-line-of-sight scanning**

The most attractive offering of RFID technology is that, unlike barcode technology, line-of-sight is not required for reading RFID tags. Multiple products can be read within a short period of time and thus reducing the time involved in counting stock. This capability assists in the mechanization of many supply chain management tasks which are normally labour intensive such as checking and scanning incoming inventory. Enterprises employing RFID technology have accurate information of stock levels on shelves. This reduces inventory costs and the frequency of out-of-stock occurrences (Michael ,2005). The result is that the retailer has access to accurate information as required for the decision making process (Huber, 2007).

- **Shelf replenishment**

Shelf replenishment is a critical, time consuming process in inventory. Poor management can lead to out of stock situations that can result in losses in sales. Shelf replenishment involves locating stock and keeping track of the stock on shelves and at the warehouse. Item-level tagging using RFID technology reduces the laborious task of inventory taking. Shelf replenishment, which is the most laborious task in the inventory management activity, is performed more accurately when using RFID technology and the inventory manager can receive all updates on inventory via Twitter anywhere and at any time through the internet (Mathaba,2011). The result is that errors due to human actions are significantly reduced.

- **Counterfeit Products**

Counterfeiting is the presentation of fake products as real products.Counterfeiting not only causes problems to the consumers, and the reputation of the retailer, but it also affects a country’s economy. It promotes losses to product inventors, job losses, affects tax revenues, research and development, and consumer safety. With RFID, customers are offered a platform with which they can query the authenticity of a product they purchase in real time (Michael,2005)

- **Labour Reduction**

RFID technology automates the most critical and laborious tasks in the inventory control activity, leading to labour reduction throughout the process in a retail industry. It has been predicted that the time required to process incoming stock can be reduced by 60-93% with the help of RFID technology; labour savings of up to 36% in order picking task can be expected, and a 90% reduction in verification costs for shipping processes are possible (Michael,2005)

- **Effective information usability and mobility**

The integration of IoT technologies enhance the information flow on critical data involving inventory processes and analysis. The easy access of information anywhere, anytime through Twitter allows inventory managers to easily make informed decisions like when to order, stock available, etc (Mathaba,2011).

7. Conclusion and Recommendations

The integration of IoT technologies supports inventory managers in their quest to remain updated on inventory levels. The proposed architecture reduces inaccuracy in the reading of RFID tagged products. Poor read rates can be easily identified by using delimiters to show the end of each category of products. In addition, the proposed architecture can also be applied to small scale enterprises. Tagging at an item level can give clear visibility and accuracy in the movement of the products in store. However the cost of RFID tags might be the hindering factor in the adoption of this technology. Further work on this research may include the reusability of RFID tags after the consumer have purchased the product. In this way the cost involved in purchasing RFID tags maybe significantly reduced.

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