Smart Retail Stores

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***Abstract*— In recent years, there were a lot of developments in the area of retail. Smart advancements like the self checkouts are implemented as well. Amazon has launched a very smart approach in retail called Amazon Go, where people can grab and go. Several sections of retail store are modified to get a smart retail store experience.**

Keywords- Radio Frequency Identification sensor(RFIDs), read range, gesture sensor, retail.

I. INTRODUCTION

Internet of things is playing a crucial role in our daily lives. Once we wake up we use our smart phones, we even ask "Hey google, What is the time?", we use smart televisions, smart blender, smart locking systems, smart cars, smart air conditioners, smart payment methods and smart elevators. They have become a huge part of our life that we can't even imagine our life without smart devices. Each sector is progressing with internet of things so as to make the tasks easier and less time taking. One of these sectors is the retail sector.

Retail industry has a lot of scope for smarter technologies, which can be very time efficient for the shoppers. Shopping is still considered to be a time taking job. For example, groceries take 2 hours on average, outfit shopping takes a lot of time since people need to try clothes on to make sure whether they fit them or not. The solution for these problems is smart retail technologies.

There are a lot of ideas for smarter retail stores like smart shelves, smart check-outs, smart search, smart information counters, smart carts, smart fridges and smart mirrors. Some of these technologies already exist but in other areas like smart search is just like the location option in smart phones. Although all of these, have successful practical use, only some of them have reasonable investment and are liked by the customers in terms of ease of usage and effectiveness.

In this paper, an IOT system is discussed in which RFID sensor, wireless communication and many smart techniques with optimized power and high security are used.

II. SENSORS

Radio Frequency Identification is the sensor which I chose as it is the most suitable for retail purpose, that is, not as small area as Near Field Communications(NFC) and not as large area as Global Positioning Systems(GPS).

Radio Frequency Identification sensor uses electromagnetic fields to determine and track the tags attached to products. There are many types of Radio Frequency Identification sensors like High frequency RFIDs, Low frequency RFIDs, Ultra-High frequency RFIDs, Active and Passive RFIDs.[1]

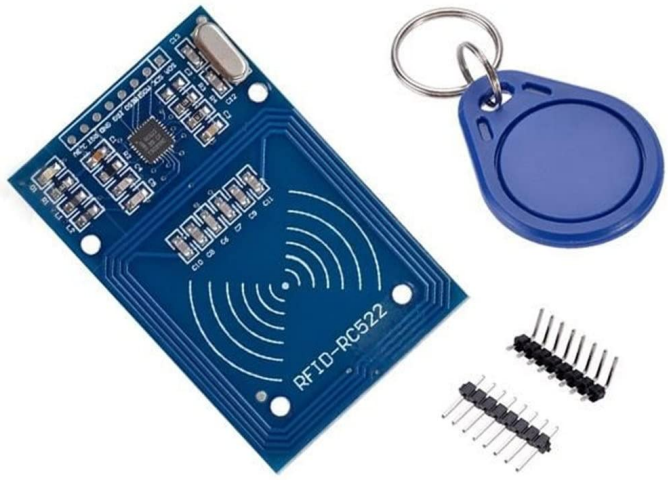

Fig. 1. RFID Sensor

A. Types of RFIDs

Low frequency RFIDs work in a smaller read range, that is, up to 10 cm and work in the range 30 KHz to 300 KHz. Although low frequency RFIDs have less read range a data reading rate is not that fast, their performance is not affected by having metals or liquids in their range.

High frequency RFIDS work in a medium read range of 10 centimeters to 1 meter and work in the range of 3MHz to 30 MHz. Near Field communications used High Frequency RFIDs. These are also used in payments, e-tickets and data transfer.

Ultra high frequency RFIDs work in a higher red range of 12 m and work in between the frequencies 300 MHz to 3 GHz. These are more sensitive to obstructions in their range like metals, liquids and other RFIDs. Ultra high frequency RFIDs have a very low manufacturing cost.

Variety of RFIDs based on frequency are discussed. There a two types of RFIDs based on communication. Those are active and passive RFIDs.2

Active RFIDs have their own power source, which is a battery. The range of these RFIDs go up to 100 meters. These are generally big in size and are costlier than passive RFIDs. Active tags are categorized into Beacons and Transponders. Transponders get activated when there is a electromagnetic signal from the reader and respond with tag data to that signal whereas Beacons are preset to be activated at a particular time.Beacons are generally used in Real time Location System (RTLS).

Passive RFIDs are charged with power by the signals coming from the reader antenna. These have a shorter read

range and the power is constrained by the signals. These are smaller in size, cheaper and more flexible than active RFIDs.

B. Working of RFID

RFIDs consist of two main components, tag the transponder and reader the transmitter or receiver.[4]

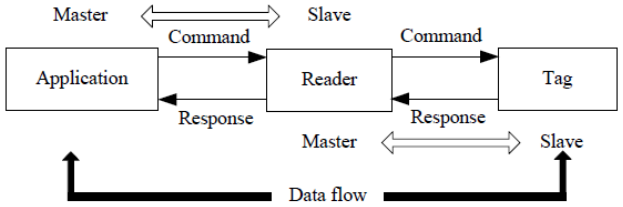

Fig. 2. Working of RFID

RFID Tag: These are attached to the products in the retail store to track, determine or count them. Tags have a coiled antenna and a chip used to store data. In this paper, I will be using both Active and Passive tags, each for different purposes.

RFID Reader: It mainly consist of a RFI module, and control unit. The purpose of it is to send a signal to tag and receive the encrypted data from the tag, then decrypt and interpret it based on the requirements.

1) RFID Tag: Any kind of RFID tag will contain 3 components, namely antenna, Integrated Circuit and PCB (Printed Circuit Board).

Communication happens mainly through the antenna, it transmits and receives radio waves to and from the reader. The antenna follows coupling mechanism as conversion of energy takes place in the form of electromagnetic radiation. Antenna will be able to collect required energy to charge other devices without a power source for itself.

The integrated circuit (IC) is collaboration of different constituents which form the crucial part of the RFID tag. RFID is just like microprocessor in other IOT systems but less complicated. The main aim of IC is to broadcast the unique ID of stored in the tag. The IC is responsible for controlling all the components and collecting all the other relevant information and adding it into the sending data(ID).

PCB is a board that holds the constituents of the RFID tag together. The purpose of each tag would be different, like the tags attached to clothing can sustain in the air conditioning of stores whereas tags attached to products like milk and frozen items needs to be a material which will not be affected even at extreme temperatures. Material here would be chosen based on the environment the tag is placed in.There are different classes of RFID tags defined by EPC Global.

Class 0 and Class 1 come under the basic Radio Frequency passive tags, Class 0 is programmed by factories whereas Class 1 is programmed by users.

Class 2 has some features extra like cyphering and read-write Radio frequency memory.

Class 3 uses battery power with a longer read range.

Class 4 Communication and extra sensing are added in this class. Active tags are used too.

Class 5 has sufficient power to initiate other tags as well.

As we can already see Passive tags are used in Classes 0 to 3 whereas Active Tags are used in Class 4. Class 5 tags are used for special purposes where a tag needs to communicate with another tag in the range.

2) RFID Reader: The RFID readers or interrogators question tags when the tags are in the range. The reader should initiate a signal for the communication to take place. RFID also has the responsibility to give the data received to an application where the data can be further used.

Readers generally consist of two main components, those are the high frequency interface (which consist of transmitter and the receiver) and control system. An application should be designed to manage the whole process.

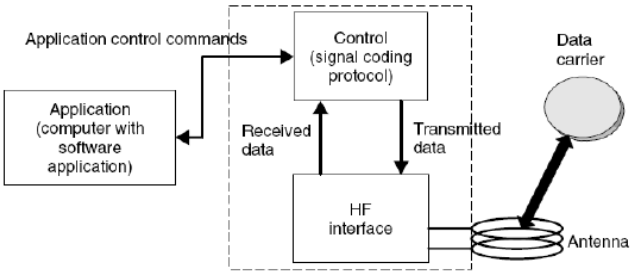

Fig. 3. Reader in RFID

The High frequency interface accomplishes various purposes like producing power of high frequency to initiate the responder (transponder in this case) and keep supplying power to it, sending data to the transponder in between power generation, receiving high frequency response from the tag.

Control unit performs tasks like communicating with the software application and following instructions from application, controlling data transfer with the tag as shown in figure 3 and encrypting and decrypting signals. There are some complex tasks as well like authentication between the reader and the transponder and including an non-collision algorithms.

The control unit relies on microprocessor to perform these complex operations like crypting, signal coding and ciphering.

In my model, smart trolleys, smart shelves, Smart Information centre, Smart fridges, Smart checkouts, Smart product count, all these features use RFID sensor only. Smart mirrors use a gesture sensor called RGB and Gesture Sensor - APDS-9960, where it identifies the gesture of people to select and try on different dresses in that retail clothing store.

I chose this sensor because of all the desirable and suitable features like:

1) Senses the proximity: Accurate values, Quality LED, Compatible with the model, Offset substitution, IR LED can be programmed using a software, Gesture not in range-determiner.
2) Senses complicated gestures : Determines all the directions, Offset substitution, First in First out storage of

Fig. 4. Gesture Sensor - APDS-9960

32 sets of data, I^2C communication which is interrupt driven

3) Friendly Interface of I^2C Bus: Provides very good Data Rate which can go up to 400 kHz, Pin which is useful for determining interruptions.

III. Communication

We already know that there are two important constituents in RFID sensor, which are tag and the reader. When tag enters electromagnetic field of the reader, a voltage is generated in its antenna coil due to induction which provides the power supply for the tag. As the tag is charged now, it can read the transmitted data and respond with the unique ID data to the reader. This process is called load manipulation. Changing the load at antenna of the tag has impact on the power consumption at reader's antenna which is considered as a voltage drop. Communication here follows the Serial Peripheral Interface (SPI).

Backscattering is one more way to transfer data. In this process, the tag uses part of the transmitted power to produce another electromagnetic field which will be received by reader's antenna.

There are many advantages of using RFIDs in terms of communication.

1) Tag data can be accessed from a good distance. Data can be accessed from closed places too like in a cardboard.
2) Many tags can be read simultaneously. This makes it a very quick process to access the data from multiple products.
3) Data can be read from outside a cardboard box. There is no need to open a box to identify what is in it, we can just track and get the details of the product through the tag to the reader.
4) RFIDs have a longer life, therefore there is no need to worry if RFIDs would get defective before a person purchases the product.
5) RFIDs also help in Brand Protection as duplicates cannot replicate the highly secure unique identification of costly brands which are stored in RFID tags.
6) The communication becomes very much faster, there is no need for a person to constantly keep checking on product shelves which needs to be refilled, RFID automatically notifies the worker if the products are out of stock so that the worker can refill the shelves.

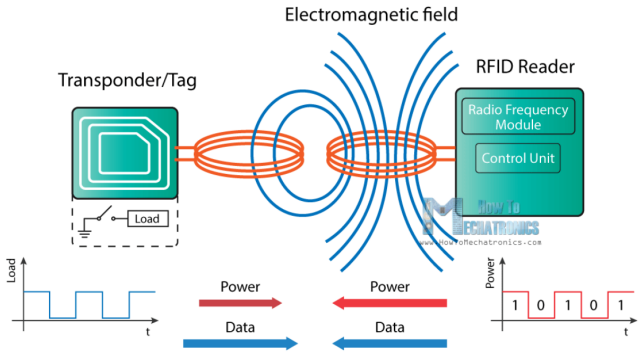

Fig. 5. Communication in RFID

There is one more type of RFID called the Battery assisted Passive (BAP) tag. In BAPs the tags gets activated only when the reader sends a signal or else the power consumption from battery is zero. This helps a lot in terms of the power required by RFID. This is known as the "reader talks first", this acts as a passive tag with sufficient power which is a desirable feature. These have a high sensitivity, therefore reader i also required to have a high sensitivity to receive the signal. The high sensitivity does not fetch in performance of the RFID.[5]

I am going to asses each type of RFID in terms of communication and choose the best fit from it.

Low frequency RFIDs penetrate through almost all the obstacles. Low frequency RFIDs may be interrupted by electrical noise produced by devices in industrial sector. LF RFIDs can read only one tag simultaneously and have less read range.

High frequency RFIDs penetrate through almost all the obstacles. High frequency RFIDs will not be interrupted by electrical noise produced by devices in industrial sector. They can read many tags simultaneously. The communication is faster than low frequency RFIDs and has a medium read range.

Fig. 6. Communication in high frequency RFID

Ultra high frequency RFIDs have faster, non-collision and higher data throughput features. They have a very poor performance around liquids and metals. They have a crowded frequency at which they work. The complicated features of RFIDs affected the faster performance of Ultra

high frequency RFIDs.

Out of these, the best suited RFID would be the High frequency RFIDs which performs best without any interference and also in a environment with metals and liquids.

There are two types of RFIDs based on power utilization too as discussed earlier, Active and Passive RFIDs. In This model, I will be using both the Active and Passive at different sections of the smart retail store.
In Gesture sensor, the communication takes place using an aurdino, I^2C protocol for communication using bread board for connections between aurdino and the I^2C 3 pins board. This aurdino can be programmed to identify the gestures of right, left, down, up, near, far and none. The connections and working of the gesture sensor is shown below.

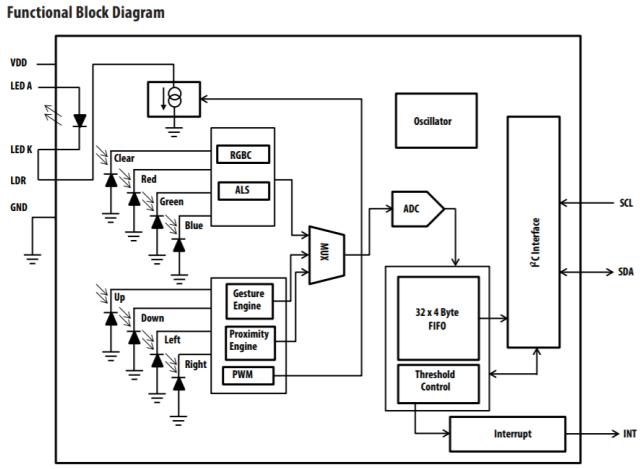

Fig. 7. Internal connections of Gesture Sensor

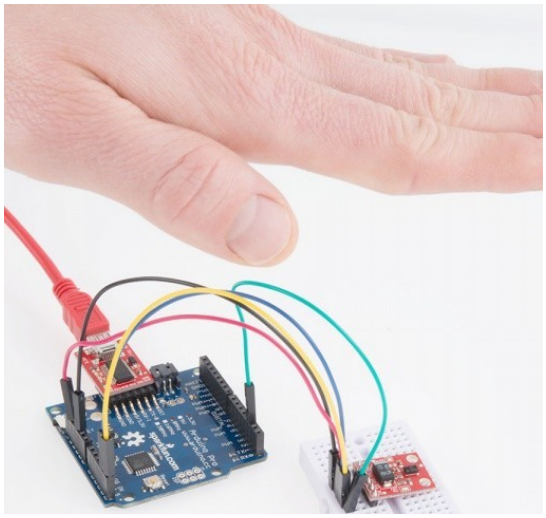

Fig. 8. Working and Connections of a Gesture Sensor

IV. Data Analysis

The data stored in tag depends on the purpose of the tag, the product cost and manufacturing details are mandatory. Along with the basic data, the location data, number of same product on the shelf data, offers data and the unique identification data will be included accordingly with respect to the purpose.[6]

The following shows an example of data in a RFID tag.

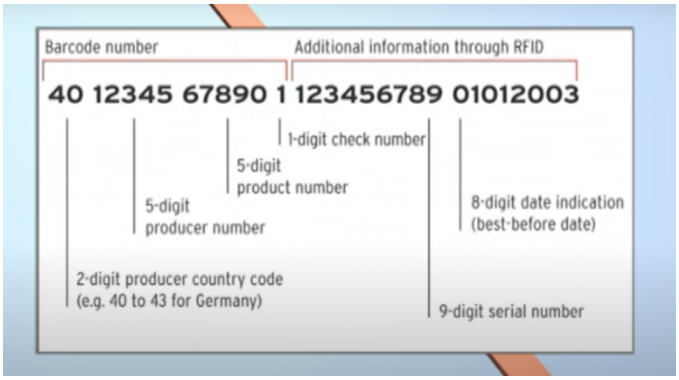

Fig. 9. Data inside a tag

As we can see in the above figure, RFID tag contains the basic information which a bar code contains like the product number, the producer number, the producer country code and also additional information like the best before information and the serial number.

The data collected in the gesture sensor depends on the direction in which the gesture has been made. To determine the gesture we need the proximity parameter. The data analysis is made as shown in the following table.

Table 1. Proximity Controls

Register/Bit	Address	Description
ENABLE<PON>	0x80<0>	Power ON
ENABLE<PEN>	0x80<2>	Proximity Enable
ENABLE<PIEN>	0x80<5>	Proximity Interrupt Enable
PILT	0x89	Proximity low threshold
PIHT	0x8B	Proximity high threshold
PERS<PPERS>	0x8C<7:4>	Proximity Interrupt Persistence
PPULSE<PPLEN>	0x8E<7:6>	Proximity Pulse Length
PPULSE<PPULSE>	0x8E<5:0>	Proximity Pulse Count
CONTROL<PGAIN>	0x8F<3:2>	Proximity Gain Control
CONTROL<LDRIVE>	0x8F<7:6>	LED Drive Strength
CONFIG2<PSIEN>	0x90<7>	Proximity Saturation Interrupt Enable
CONFIG2<LEDBOOST>	0x90<5:4>	Proximity/Gesture LED Boost
STATUS<PGSAT>	0x93<6>	Proximity Saturation
STATUS<PINT>	0x93<5>	Proximity Interrupt
STATUS<PVALID>	0x93<1>	Proximity Valid
PDATA	0x9C	Proximity Data
POFFSET_UR	0x9D	Proximity Offset UP/RIGHT
POFFSET_DL	0x9E	Proximity Offset DOWN/LEFT
CONFIG3<PCMP>	0x9F<5>	Proximity Gain Compensation Enable
CONFIG3<PMSK_U>	0x9F<3>	Proximity Mask UP Enable
CONFIG3<PMSK_D>	0x9F<2>	Proximity Mask DOWN Enable
CONFIG3<PMSK_L>	0x9F<1>	Proximity Mask LEFT Enable
CONFIG3<PMSK_R>	0x9F<0>	Proximity Mask RIGHT Enable
PICLEAR	0xE5	Proximity Interrupt Clear
AICLEAR	0xE7	All Non-Gesture Interrupt Clear

Fig. 10. Data from a Gesture sensor and implication of that data

As shown in the table above the gesture made by the person standing in front of smart mirror is determined.

V. Methodology

I am going to discuss my approach towards a smart retail sector in this section. As i have already selected my sensor which is the high frequency RFID which may be either active or passive based on the requirement which will be discussed further.

There are smart systems to incorporate in a smart retail store. Almost all of the systems will follow the following flowchart.

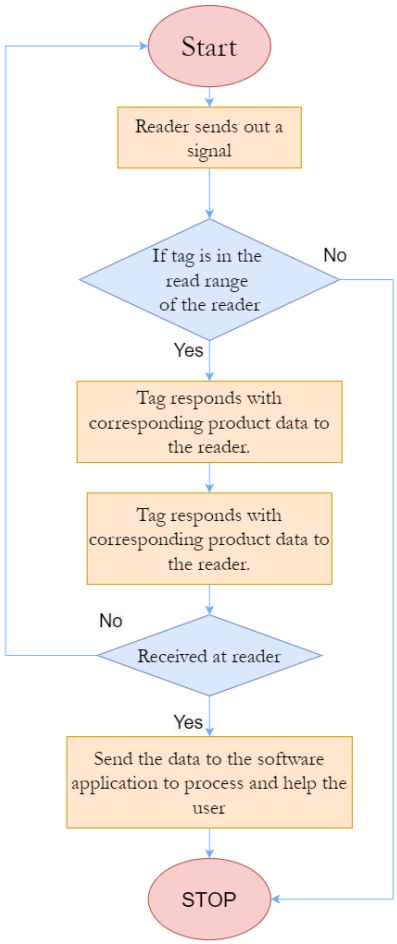

Fig. 11. Flowchart of the system

The following are the smart systems which i want to include in my model.

1) *Smart trolley:* Each customer would get a smart trolley where they can tap their customer card to identify themselves. This feature suggests them items that are related to their previous purchase. If the customer visits the store frequently, they would be eligible for bigger discounts and would be automatically updated in their accounts. These trolleys have screen display which acts as a RFID reader and has the application software as well, these help in tracking the product and showing the directions to the consumers to get that product by accessing the data from the tag of the product following the flow chart shown above.

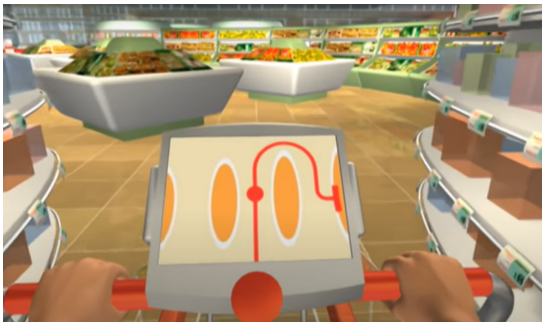

Fig. 12. Tracking a product

These trolleys can also be used by the consumer for scanning and adding the product to their checkout list. When a consumer scans the product and puts it in the cart, the shelf data of the tag is removed from the tag data to keep correct count of products in the shelf.

Fig. 13. Scanning a product at the cart itself

2) *Smart shelves* Smart shelves are equipped with a lot of updated features. To implement the smart shelves, we need to include a small data called the "shelf data" into the tag data to maintain the correct count of the products available in the shelf. Whenever a consumer takes a product out from the shelf and scans it int their cart, then the shelf data becomes 0 and the count reduces by 1. Number of same products in a store and number of same products in a shelf are different. Smart digital displays can be set on each shelf so that the display can be changed according to the special offers without the need of special stickers. The cost data will automatically be updated in the RFID tag whenever the cost on digital display changes.
These display can also be used to showcase creative advertisements or product taglines to make the product more attractive.
3) *Smart information centre* At these smart information centres, which are place at accessible places from every point in a store, one can scan the tag of the product to get all the basic information of the product, compare the nutritional and other important characteristics of

Fig. 14. Smart Price Display Boards

that product with other similar products and make the decision knowing everything about the products. These help a person who is confused to do a purchase as that person is not very sure about the features of each product.

Fig. 15. Smart Information Centre

4) *Smart fridges:* Smart fridges are same like smart shelves, the only difference is the RFID board material should be a material which can withstand extreme cold temperatures as some items are kept in the deep freezer like Ice creams, cold desserts, frozen vegetables, meat and many more. Other items are kept in the normal fridge like milk, curd, butter and cheese.
5) *Smart mirrors:* Smart mirrors are used in mainly clothing stores. They are used to see ourselves wearing a outfit without physically wearing it, This uses the body recognition feature to fit a particular outfit to the body type and show it to the customer. This uses a body recognition technology and also face recognition to save the purchases and their body type. The RFID is used same as the RFID used for different products in a grocery store. But the tag has extra attributes like size, colour, measurements, type and many others.

In many clothing stores Beacons are attached to the mirrors so that customers can access information on all the varieties of clothes available in the store using a specific application.

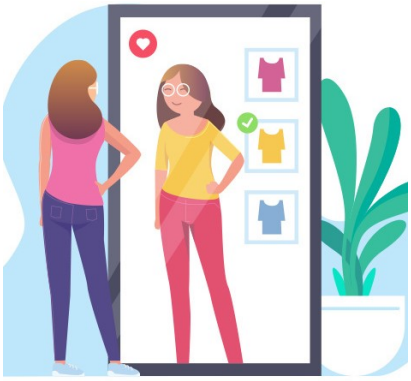

Fig. 16. Smart Mirrors

6) *Smart checkouts:* After completing the shopping, a person arrives at a counter where the whole cart with product tags is scanned and a bill is generated where the customer can tap credit or debit card or phone to complete the payment. If a person keeps a particular product back, the shelf number remains 0 until it is placed in the same shelf but the count of the number of the same product goes up by 1.

Fig. 17. Smart Checkout System

7) *Smart product count:* As the customers keep buying products, the product count in the store are updated to the warehouse nearby that the count is nearing to finish, so that the products can be sent to that particular store. This reduces the employment in the store to keep checking on the stock whether the available stocks are sufficient or not. Ultra High frequency RFIDs should be used for this purpose. The only constraint for this feature is that the warehouse should be less than 500

m away from the store. The warehouse in turn updates the Distributor about the product count.

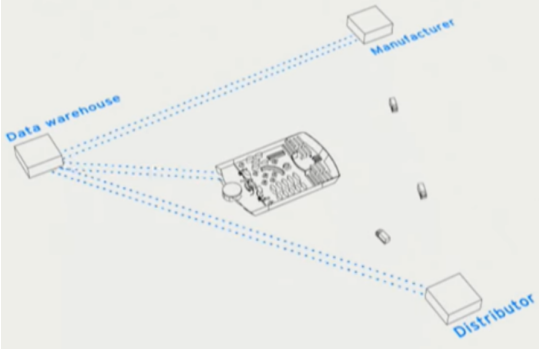

Fig. 18. Smart communication from retail stores

Fig. 19. Methodology of the model

VI. Power

There are different power requirements for different RFIDs. Battery Assisted Passive RFIDs are most efficient in saving power consumption as they get activated only when a query is produced by RFID reader. BAP RFIDS have the least power consumption.[7]

The power consumption of other RFIDs depends on the range of reader. If the range of reader of a RFID is more, the power consumption is more as well and vice-versa.

If the retail store is bigger in size, then we require a larger read range which will in turn require higher power whereas a smaller retail store will require lot less power.

There can be power saving mode in a RFID as already discussed. The tag gets activated only in the read range of the reader. Power can only be saved if there are no tags in the field of reader. It is an efficient way to reduce power consumption without reducing the read range. Power consumption in different power save modes are shown below.

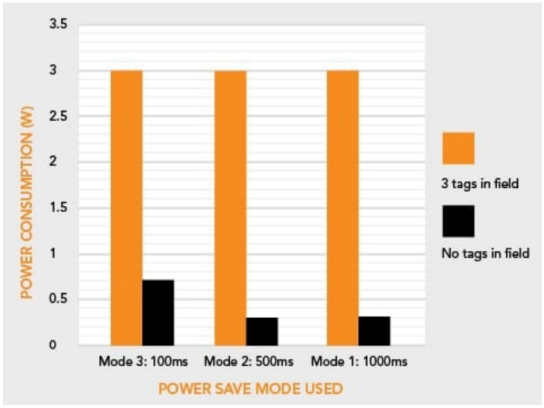

Fig. 20. Power Consumption Vs Distance of the tags

One more way to reduce power consumption in an RFID is to use a RF off time parameter. RF off time parameter turns off the power and transmission for a selected period of time. This reduces the mean power used irrespective of whether tags are present in the read range or not. The disadvantages of this power saving method are: the read speed decreases, tags cannot be read in a given time period. The power consumption with different RF off time parameters is shown below.

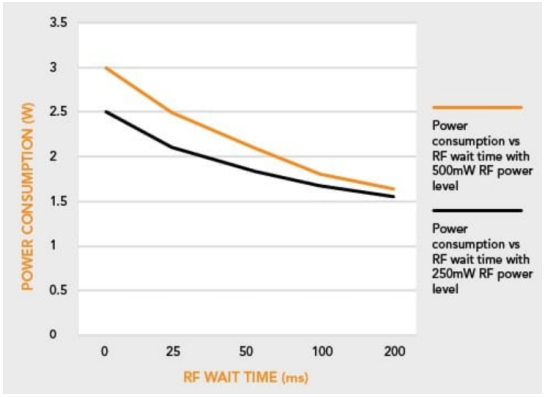

Fig. 21. Power Consumption Vs RF off time parameters

In the High frequency active RFID which I am using in this model, the off time parameter can be used but only at nights when the store is closed since the tags should be working whole day since the customers would want to access products when the store is open. So we use the technique activating the tag only when in the reader's range. Although not a lot of power is saved in this process but saving some is better than saving none.

Power consumption in our model runs on battery since it is an active tag, therefore, the batteries should have the capacity to sustain till the product gets sold, if the product has a sooner expiry, the product can be connected to a tag with enough battery to last till its expiry.

The power consumption in Gesture sensor is 2.4 to 3.6 V for the sensor and LEDs need a 3.0-4.5 V of power. Since this is the general power Supply, smart mirrors can easily be accommodated inside retail stores.

Pin Label	Description
VL	Optional power to the IR LED if PS jumper is disconnected. Must be 3.0 - 4.5V
GND	Connect to ground.
VCC	Used to power the APDS-9960 sensor. Must be 2.4 - 3.6V
SDA	I^2C data
SCL	I^2C clock
INT	External interrupt pin. Active LOW on interrupt event

Fig. 22. Power Consumption Vs Distance of the tags

VII. Security

There are a lot of security issues faced in our model, some of them are[8]:

1) Hackers can get into the system and duplicate any product ID stored in a tag and then take the product from the store just portraying as if they are actually buying the product. This may not happen if the tag data is encrypted.
2) The privacy of a person is at stake in case of smart mirrors as the person might not be comfortable with his/her face being recorded but do want to try the clothes virtually.
3) Interruptions like a person can jam the data transmission between the tag and the reader with jammers, physical force or just removing the RFID tag from the product.
4) People can easily clone and spoof so that they can gain access to the whole database of product information. They can use this information for many number of malpractices.

VIII. Conclusion

My model here accomplishes some of the smart features that customers expect from a smart retail store. All the main challenges for a retail store like the adaptability, security and privacy are taken care of in this model. There are some constraints in this model too like any other model. Some of the constraints include the read range which cannot be beyond 600 metres in store, this would not be a problem for smaller stores, but stores with a bigger diameter would prefer other sensors which offer distant communications as well. Adaptability for this model would be very easy and customer friendly since the customers can easily learn, understand and get acquainted to this technology. Minimalistic Power usage is also ensured as the best approach in power saving is taken in this model. Therefore, this model would make a very competent model in the present retail industry.

IX. Future Scope

There would be a lot of new technologies coming up everyday, any new technology can be implemented upon this model unless and until the sensor itself needs to be changed. I am sure that soon retail industry would be very much advances, time efficient, interesting and a very joyful process.

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