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Smart Passenger Exit Control System [SPECS] for Baggage Security at Airports

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Abstract — *Airport Baggage Security has seen giant strides over the last decade. The instances of baggage loss occurring in the span between check-in at the source airport and baggage insertion on the carousel during check-out at the destination airport have reduced tremendously in the past few years. This has been made possible by using the latest sophisticated baggage tracking technologies. However once the baggage arrives on the carousel of the destination airport, there is no system in place to prevent a passenger from picking up baggage which does not belong to him except for being vigilant while awaiting his baggage. Thus, this is a chink in the baggage security system. In this paper, we discuss the amalgamation of the two wireless technologies – Radio Frequency Identification [RFID] and ZigBee to achieve one principal goal – Preventing the theft of Passenger Baggage at Destination Airports, while checking out. The aim here is to ensure that a passenger leaves the airport premises with his baggage only and not any other passenger's baggage. If he happens to be carrying the baggage of another passenger an alert will be raised, enabling identification of the errant passenger and the baggage in question can be retrieved by security personnel.*

Keywords- *RFID, LF RFID Tag, UHF RFID Tags, RFID Reader, ZigBee, Airport, Security, Passenger Baggage, Carousel, Smart Passenger Exit Control System [SPECS], Exit Gate, Passenger Exit Control System I [PECS I], Passenger Exit Control System II [PECS II], Passenger/Baggage Authentication System [PBAC], Authentication Success Message, Authentication Failure Message, Baggage Identification Success Message, Baggage Identification Failure Message, Exit Gate Control Mechanism,*

I. INTRODUCTION

While analysing Passenger Baggage Management System at major airports, one common problem comes to light – The security of passenger baggage on the carousel at the time of check out. It has been found there are no restrictions on the pick-up of baggage from the carousel. In fact there have been instances when a passenger picks up the baggage of another passenger either due to genuine misunderstanding due to similarity in baggage or with the distinct intention to pilfer. This causes a lot of inconvenience to the affected passenger and is indeed a weak link in the current baggage security system. Any person waiting at the baggage carousel to pick up his baggage will surely weigh the distinct possibility of someone else picking up his baggage, which leads to unease.

This paper proposes a solution to this problem – A Smart Passenger Exit Control System [SPECS] which prevents a passenger from leaving the airport premises with baggage that does not belong to him. The system is installed near the airport exit. As the passengers leave the carousel area after picking up their baggage they have to move through the SPECS. The SPECS authenticates the bonafides of the passenger and verifies the ownership of the baggage carried by the passenger. Only after this two level authentication process is successful, the passenger is allowed to leave the airport with his legitimate baggage. If there is an authentication failure the SPECS will immediately raise an alert which will enable security personnel to detain the errant passenger and retrieve the baggage from him. This entire process gets completed very quickly and causes minimal delay to bonafide passengers,

While the SPECS will not physically prevent a passenger from picking up the wrong baggage from the carousel, it will certainly prevent the passenger from leaving the airport with the wrong baggage and aid in efficient baggage retrieval. This system is easy to implement and also involves nominal investment. Also, the level of training required for both personnel and passengers is minimal.

II. LITERATURE SURVEY

While designing the new proposed system, a study of the existing baggage security and tracking systems currently operational in some major airports around the world was carried out using publicly available information on the web. Various technical papers relating to the study of RFID for baggage tracking at airports along with the use of ZigBee networking protocol were referenced to get an idea on the existing work being done in this field [1],[2],[3],[4],[5]. In order to obtain a broad overview of the practical implementation of these technologies, current technical papers on Security Management applications for Smart Homes, Shopping Malls and Parking lots using RFID and ZigBee technology were also researched [6],[7],[8],[9].

In almost all modern systems the use of RFID has become inherent to baggage tracking. It is found that the use of RFID technology can provide increased productivity and security.There is improved traceability because of better read rate than barcode technology.

A network of RFID readers, associated PC Terminals and a Centralised Database needs to be developed at the airport to ensure tracking of passenger baggage. While there are multiple options for creating a network, ZigBee appears to be the best bet on account of its low power consumption, low cost, wide range, high reliability and better security.

2.1 RFID Technology

Radio Frequency Identification [RFID] is an automatic identification and logging technology.

Three components constitute an RFID system, namely:

- The Tag
- The Reader and
- The Host.

The Tag [also known as transponder] consists of:

- ✓ A Silicon microchip and
- ✓ An antenna

The **Tag's Chip** or **Integrated Circuit (IC)** delivers performance, memory and extended features to the tag. The chip is pre-programmed with a tag identifier (TID), a unique serial number assigned by the chip manufacturer, and includes a memory bank to store some information. For example, many tags contain only a bar code number and security bits but some tags contain some additional information as well. An RFID tag can be attached to or incorporated into an item for the purpose of identification.

Tag antennas collect energy and channel it to the chip to turn it on. Generally, the larger the tag antenna's area, the more energy it will be able to collect and channel toward the tag chip, and the further read range the tag will have.

Tags can be classified as:

- Passive**,**
- Active or
- Semi-active [Battery Assisted Passive (BAP)]

Passive tags do not have a power source, but rather draw power from the incident electromagnetic field transmitted by the Reader antenna. Hence the Reader has to transmit sufficient power to provide energy to the tag that transmits back stored data. When the tag is subjected to these RF waves, it draws power which is used to retrieve information from the tag memory and transmit this information to the Reader.

As passive system ranges are limited by the power of the tag's **backscatter** [the radio signal reflected from the tag back to the reader], they are typically short from a few centimetres to less than10 meters. Because passive tags do not require a power source or transmitter, and only require a tag chip and antenna, they are cheaper, smaller, and easier to manufacture than active tags.

Active and Semi Active tags require a power source – usually a battery for operation.

Tags can be Read Only [RO], Write Once Read Many [WORM] or Read Write [RW].

For the proposed system under consideration we make use of Passive Tags, as they do not require a significant scanning range and have a relatively small size.

The RFID Readers are composed of:

- ✓ A Radio Frequency module,

- ✓ A control unit and
- ✓ An antenna to interrogate electronic tags via Radio Frequency (RF) communication

The main function of a Reader is to ensure that a tag can be reliably read as it passes through the "interrogation zone". The interrogation zone refers to the range over which a reader can read the tag. The interrogation zone may be of different sizes depending on the type of tag and the power of the reader. Passive tags, with shorter read ranges, tend to operate within a smaller interrogation zone.

Just like RFID tags, there are many different sizes and types of RFID readers. Readers can be affixed in a stationary position in a store or factory, or integrated into a mobile device such as a portable, handheld scanner. Readers can also be embedded in electronic equipment or devices, and in vehicles. In general, Readers can be hand-held or mounted in strategic locations.

Reader antennas convert electrical current into electromagnetic waves that are then radiated into space where they can be received by a tag antenna and converted back to electrical current. Just like tag antennas, there is a large variety of reader antennas and optimal antenna selection varies according to the solution's specific application and environment.

The **Host** implements RFID Reader Control and runs the Application Software. Reader Control and Application Software, also known as middleware, helps connect RFID readers with the applications they support. The middleware sends control commands to the reader and receives tag data from the reader, which is used by the application software running on the Host.

2.1.1 RFID Frequencies

RFID systems throughout the world operate in three bands:

- ✓ Low frequency (LF),
- ✓ High frequency (HF) and
- ✓ Ultra-high frequency (UHF) bands

Radio waves behave differently at each of these frequencies with advantages and disadvantages associated with using each frequency band.

If an RFID system operates at a lower frequency, it has a shorter read range and slower data read rate, but increased capabilities for reading near or on metal or liquid surfaces. If a system operates at a higher frequency, it generally has faster data transfer rates and longer read ranges than lower frequency systems, but more sensitivity to radio wave interference caused by liquids and metals in the environment.

The LF band covers frequencies from 30 KHz to 300 KHz. Typically LF RFID systems operate at 125 KHz, although there are some that operate at 134 KHz. This frequency band provides a short read range of 10 cm, and has slower read speed than the higher frequencies, but is not very sensitive to radio wave interference.

The HF band ranges from 3 to 30 MHz. Most HF RFID systems operate at 13.56 MHz with read ranges between 10 cm and 1 m. HF systems experience moderate sensitivity to interference.

The UHF frequency band covers the range from 300 MHz to 3 GHz. Systems complying with the UHF Gen2 standard for RFID use the 860 to 960 MHz band. While there is some variance in frequency from region to region, UHF Gen2 RFID systems in most countries operate between 900 and 915 MHz.

The read range of passive UHF systems can be as long as 12 m, and UHF RFID has a faster data transfer rate than LF or HF. UHF RFID is the most sensitive to interference, but many UHF product manufacturers have found ways of designing tags, antennas, and readers to keep performance high even in difficult environments. Passive UHF tags are easier and cheaper to manufacture than LF and HF tags.

The bulk of new RFID projects are using UHF opposed to LF or HF, making UHF the fastest growing segment of the RFID market. [10]

2.2 ZigBee

When it is required to build wireless networks where low data communication rates and low power consumption are required, a wireless networking protocol referred to as ZigBee is found to be very suitable. This is a low cost technology which is targeted towards automation and remote control applications.

A major advantage of Zigbee is its ability to provide low power connectivity for equipment that needs very long battery life even up to several years but does not require high data transfer rates as compared to Bluetooth. In addition, ZigBee networks can be designed to work in mesh configuration and far surpasses Bluetooth in size and reach.

ZigBee compliant wireless devices are expected to provide a range of 10-75 meters, depending on the RF environment and the power output consumption required for a given application. The bands reserved for ZigBee Communications are: 2.4 GHz global, 915 MHz Americas or 868 MHz Europe bands. The data rate is 250kbps at 2.4GHz, 40kbps at 915MHz and 20kbps at 868MHz.

Zigbee often uses a basic Master – Slave configuration suited to static star network of many infrequently used devices that talk via small data packets. Other network topologies such as peer to peer and cluster tree are also used. When Zigbee is powered down, it can wake up and get a packet in around 15 ms. Network routing schemes are designed to ensure power conservation, and low latency through guaranteed time slots. [11]

III. PROPOSED SYSTEM

After collecting his baggage from the baggage carousel, the passenger proceeds towards the airport exit gate. In our proposed design the passenger will have to move through a Smart Passenger Exit Control System [SPECS] before exiting the airport.

The SPECS proposes the following installations in the check-out zone of existing airports:

i. Two Exit Gates designated Exit Gate #1[Penultimate] and Exit Gate #2 [Final] through which each passenger has to pass after picking up his baggage from the carousel,
ii. A Passenger Exit Control System I [PECS I] linked to and co-located with Exit Gate #1 on the entry side,
iii. A Passenger Exit Control System II [PECS II] linked to Exit Gate #2 and co-located with Exit Gate #1 on the exit side and
iv. The Passenger/Baggage Authentication Centre [PBAC] wirelessly linked to PECS I and PECS II.

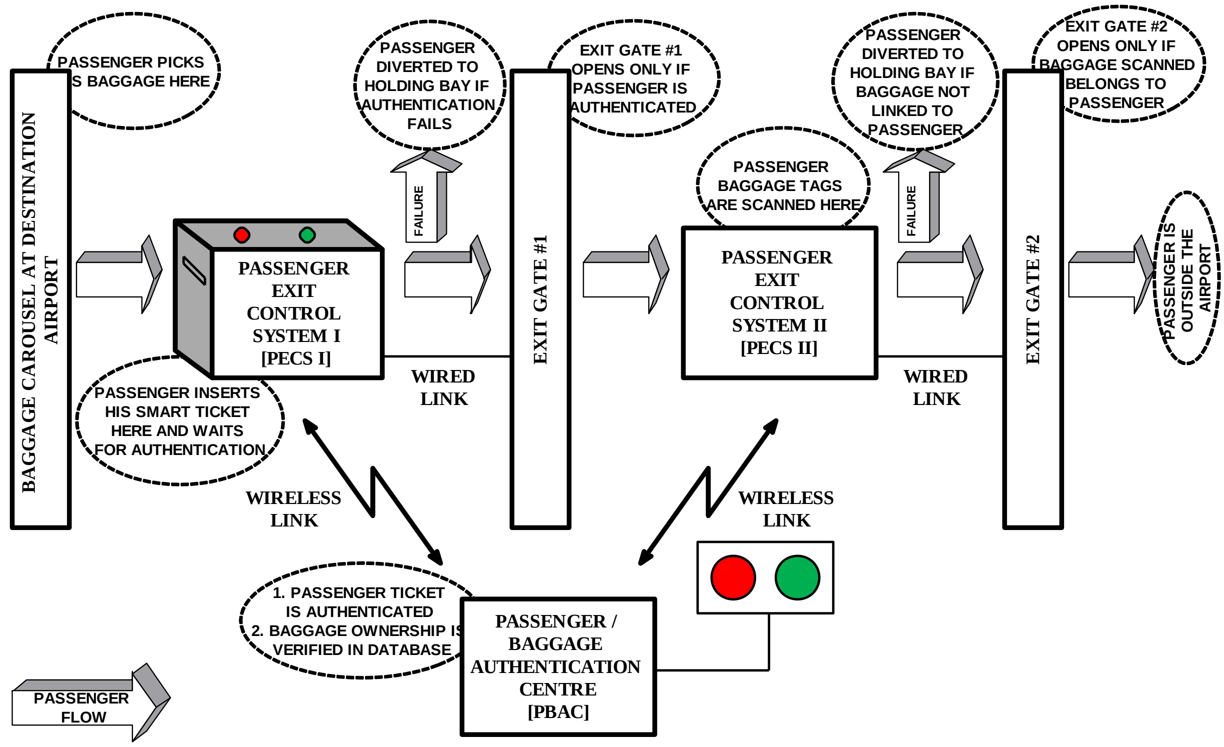


Figure 1. Smart Passenger Exit Control System [SPECS]

The figure 1 above shows the block diagram illustrating the Smart Passenger Exit Control System [SPECS] along with the movement flow of Passenger with Baggage from the instant the passenger picks up the baggage off the carousel to the instant the passenger with baggage finally exits from the destination airport.

While moving towards the airport exit, the passenger first encounters the PECS I

The following actions takes place at the PECS I

i. The passenger inserts his Smart Ticket [containing LF RFID Tag] in the slot provided.
ii. The PECS I transmits the unique ID of the passenger to the PBAC
iii. The PBAC authenticates the passenger and depending on the result of authentication transmits an Authentication Success Message or Authentication Failure Message to the PECS I
iv. If PECS I receives an Authentication Success Message it causes a Green LED Light on the Smart Ticket insertion panel to glow and causes the Exit Gate #1 to be thrown open. This allows the passenger to move forward through this Exit Gate.
v. If PECS I receives an Authentication Failure Message it causes a Red LED Light on the Smart Ticket insertion panel to glow. The Exit Gate #1 will continue to remain closed in this case. The passenger will be directed to move to a Holding Bay and be detained there till security clearances are obtained.

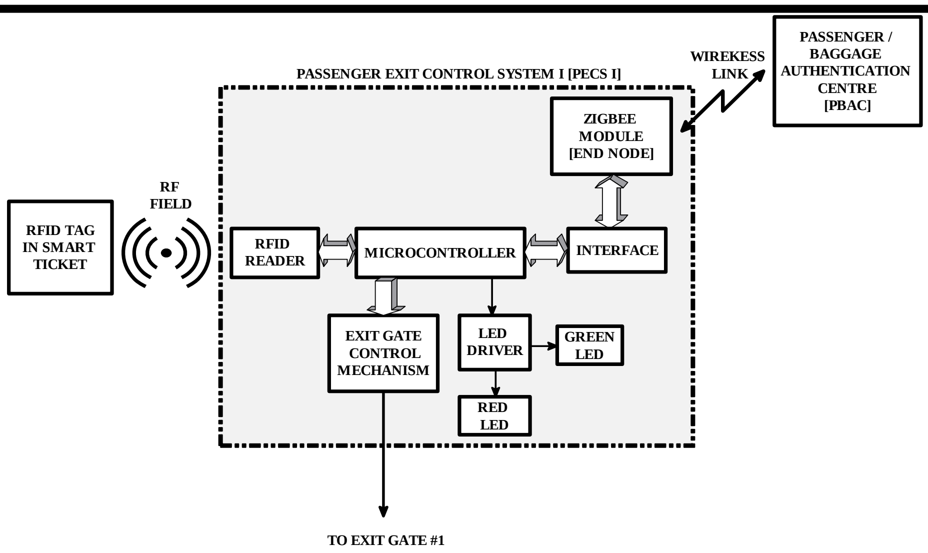
When the Positive Authenticated passenger reaches the other side of the Exit Gate #1, he encounters the PECS II

The following actions take place at the PECS II

i. As the passenger baggage passes through the Smart Gate, the UHF RFID tags on each baggage item is read by the PECS II
ii. The PECS II transmits this information wirelessly to the PBAC.
iii. The PBAC carries out an authentication process to verify whether each baggage item belongs to the passenger accompanying the baggage. Also the number of baggage items will be tallied with the number of baggage items during check in at the source airport.
iv. If authentication is successful, the PBAC causes a Green LED Light mounted on a panel nearby to glow [till it receives a message from the PECS II] and sends a Baggage ID Success Message to the PECS II.
v. If authentication fails, the PBAC causes a Red LED Light mounted on the same panel to glow for some time and sends a Baggage ID Failure Message to the PECS II.
vi. If PECS II receives a Baggage ID Success Message it causes the Exit Gate #2 to be thrown open. This allows the passenger to move forward through it and exit the airport. After the passenger exits, the PECS II sends an 'LED Light turn OFF' message to the PBAC.
vii. If PECS II receives a Baggage ID Failure Message it causes the Exit Gate to be closed. The passenger will be directed to move to the Holding Bay and be detained there till security clearances are obtained.

3.1 Passenger Exit Control System I [PECS I]

The figure below shows the block diagram of the Passenger Exit Control System I [PECS I]



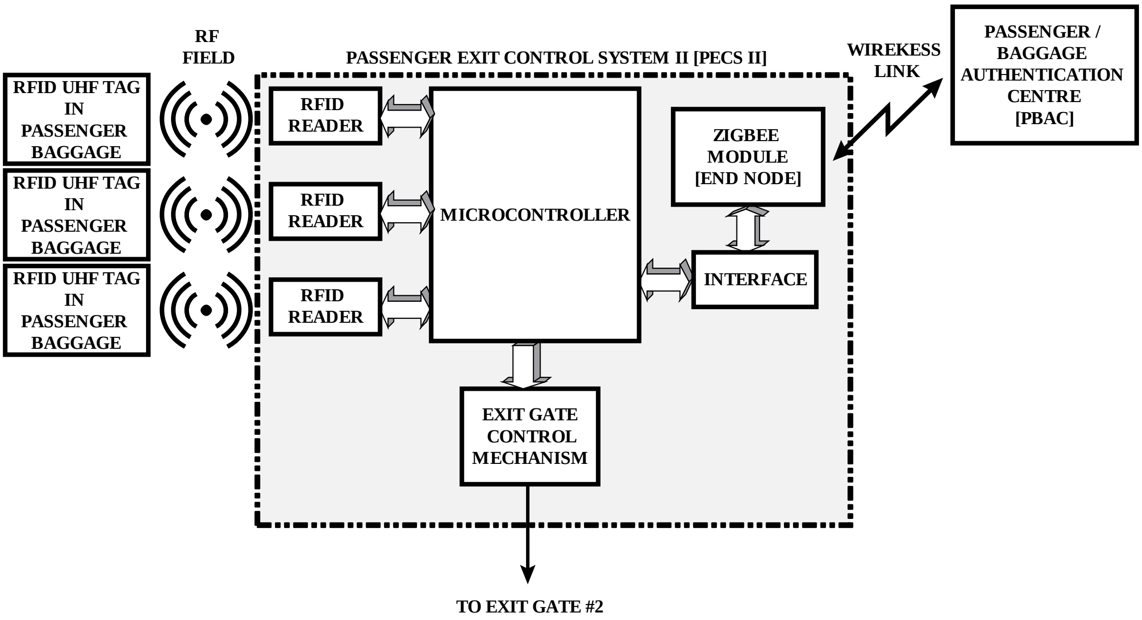
At the PECS I, the passenger inserts his Smart Ticket in the slot provided. This causes the RFID Reader of the PECS I to read the Unique ID of the passenger's Smart Ticket. This information is input to the microcontroller connected to the RFID Reader and is then wirelessly transmitted to the PBAC using the ZigBee Module [A ZigBee Reduced Function Device [RFD] configured to operate as an End Node] interfaced to the microcontroller.

The PECS I ZigBee Module receives an authentication message from the PBAC. This message is read and processed by the microcontroller. If the passenger authentication is successful, the microcontroller drives the Exit Gate Control Mechanism to open the Exit Gate #1 and also flashes ON a Green LED Light providing visual indication of successful authentication. Hence the Passenger can move ahead with his baggage towards the Exit Gate #2.

Once the passenger with baggage crosses the Exit Gate #1, the microcontroller drives the Exit Gate Control Mechanism to close the Exit Gate #1 and also switches OFF the Green LED Light. If the passenger authentication fails, the microcontroller sends no signal to the Exit Gate Control Mechanism and the Exit Gate #1 remains closed. Also, it causes a Red LED Light to flash ON for some time providing visual indication of authentication failure and the passenger is directed to the Holding Bay and detained there till security clearances are obtained.

3.2 Passenger Exit Control System II [PECS II]

The figure below shows the block diagram of the Passenger Exit Control System II [PECS II]

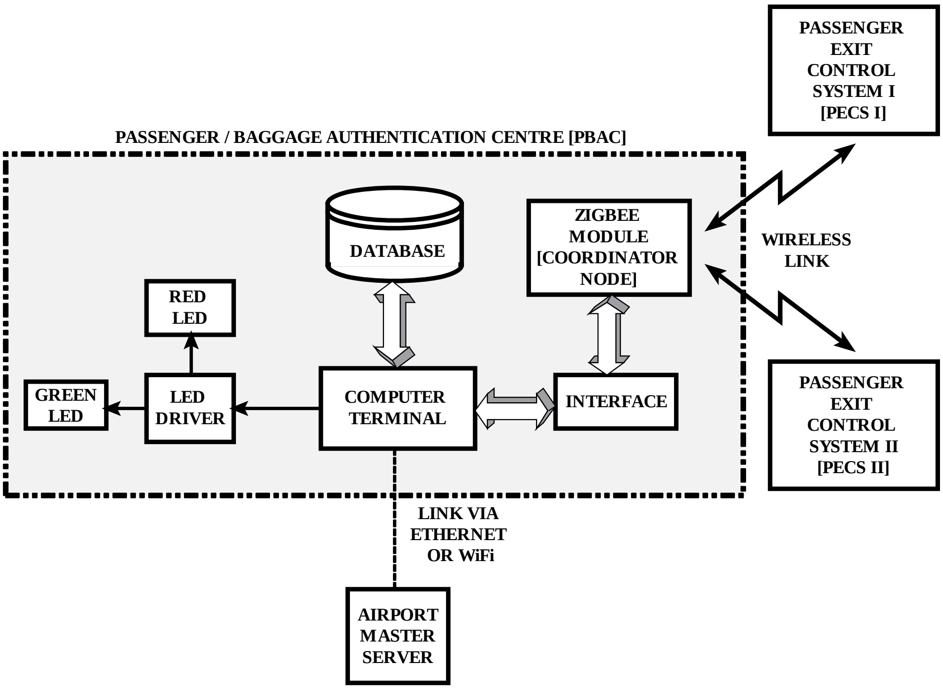


In this system, the RFID readers are mounted at strategic points on two specially erected rectangular structures, just near the exit side of Exit Gate #1. These rectangular structures are placed parallel to each other in such a way that the passenger with baggage must pass through the area in between the two structures referred to as the PECS II 'interrogation zone'. This arrangement ensures that the UHF tags on every item of baggage falls within the range of at least one RFID reader when the baggage leaves the Exit Gate #1 and enters the PECS II Scanning Zone. On account of presence of multiple RFID readers placed at strategic points, the tag ID information on each baggage item will be reliably read. This information is input to the microcontroller and then wirelessly transmitted to the PBAC using the ZigBee Module [A ZigBee Reduced Function Device [RFD] configured to operate as an End Node] interfaced with the microcontroller.

The PECS II ZigBee Module receives a Passenger Baggage Identification message from the PBAC. This message is read by the microcontroller interfaced with the ZigBee Module. If the Passenger Baggage Identification is succesful, the microcontroller drives the Exit Gate Control Mechanism to open the Exit Gate #2 thereby allowing the passenger to exit the airport with his baggage. Once the passenger with baggage crosses the Exit Gate #2, the microcontroller drives the Exit Gate Control Mechanism to close the Exit Gate #2 and also sends a message to the PBAC via the ZigBee Module to switch OFF the Green LED Light. If the Passenger Baggage identification fails, the microcontroller sends no signal to the Exit Gate Control Mechanism and the Exit Gate #2 remains closed. The passenger is now directed to the Holding Bay and detained there till security clearances are obtained.

3.3 Passenger/Baggage Authentication Centre [PBAC].

The figure below shows the block diagram of the Passenger/Baggage Authentication Centre [PBAC].



Stage 1: Passenger Authentication [PECS I Link]

The Passenger Ticket ID information from the PECS I is received by the PBAC ZigBee Module [A ZigBee Full Function Device [FFD] configured to operate as a coordinator node]. This information is read by the computer interfaced with the ZigBee Module. Using Data Base Management Software, the received Passenger ticket ID is now correlated with Passenger ticket ID information stored in the local database [updated from the Airport Master Server]. If the two IDs match, then an Authentication Success Message is sent to the PECS #1 via the ZigBee Module else an Authentication Failure Message is sent.

Stage 2: Baggage Ownership Verification [PECS II Link]

The Baggage UHF RFID Tag ID information from the PECS II is received by the ZigBee Module. This information is read by the computer interfaced with the ZigBee Module. Using Data Base Management Software, the received Baggage UHF RFID Tag ID is correlated with Baggage UHF RFID Tag ID information of the Passenger which is stored in the local database [updated from the Airport Master Server]. If all the received baggage tag IDs match with the stored baggage Tag IDs for the passenger then a Green LED Light flashes ON providing visual indication of positive baggage identification and a Baggage Identification Success Message is sent to the PECS II via the ZigBee Module. When the PBAC receives a turn OFF message from the PECS II, the Green LED Light is switched OFF.

If even one of the received baggage tag IDs do not match with the stored baggage Tag IDs for the passenger then a Red LED Light flashes ON for some time providing visual indication of baggage identification failure and a Baggage Identification Failure Message is sent to the PECS II via the ZigBee Module.

3.4 Software Development

Applications for the various units of the system are proposed to be developed in Visual Studio using C#. Microcontroller programming is proposed to be carried out using C using MPLAB IDE.

IV. CONCLUSION

In this paper, a new system titled, "Smart Passenger Exit Control System [SPECS] has been proposed. This system aims at ensuring that no passenger can exit the airport with baggage that does not belong to him. This in turn would dissuade any person with malafide intent from picking up someone else's baggage from the carousel. Even if a passenger inadvertently picks up the baggage of another passenger from the carousel, this action would be detected by the SPECS before the errant passenger leaves the airport. We can therefore conclude that baggage security after pick up from the carousel at the destination airport is greatly enhanced by the introduction of SPECS.

Furthermore, the possible implementation of this system was also discussed. With the solution proposed in this paper the scope for baggage theft would be greatly reduced, if not completely eliminated, hence passenger satisfaction at airports would be greatly enhanced.

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