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DESIGN AND IMPLEMENTATION OF TRACKING PERSONNEL WITHIN BUILDING FEATURING FPGA AND RFID

Muataz H. Salih, Lim H.Teng and Saif N. Ismail
School of Computer and Communication Engineering, Universiti Malaysia Perlis (UniMAP) Perlis, Malaysia
E-Mail: muatazhameed@gmail.com

ABSTRACT

Nowadays, personnel tracking become a significant topic in terms of security, confinement, achievement and permission purposes. There is Global Positioning System which is popular and available for outdoor personnel tracking however it is restricted for indoor tracking. Currently, indoor tracking system only has the ability to track the location of personnel but not their direction of movement. When it comes to practical, the feature of tracking direction of movement can become one of the important features to get more accurate localization information. Besides, latency on getting location information of a person by asking around the people is not realistic as someone might lost the information to find their targeted person exact location. Thus, an indoor personnel tracking system is designed and implemented to track the not only the location but also the direction of movement and able to get the latest information through mobile application. The potentials of Field Programmable Gate Array (FPGA) and concept of Internet of Things (IoT) are applied into this system in order to improve the system performance by increasing the system throughput and decreasing the system cost. This system is implemented on FPGA DE1-SoC board by integrating with WiFi modules and Radio-frequency Identification (RFID) system. The system has the ability to add new client data onto FPGA memory for next time tracking purpose.

Keywords: internet of things (IoT), radio-frequency identification (RFID), WiFi, FPGA design.

INTRODUCTION

Recently, tracking of personnel is one of the interests of numerous corporation and institution for the security, confinement, achievement and permission purposes. GPS is a standout amongst the most well-known advancement has been utilized by individuals in tracking individuals, be that as it suited for alfresco condition however not fitting for personnel localization inside a building. This is on the grounds that GPS is a satellite-based positioning framework that uniquely intended for an outside or open region. In addition, there are some primary deficiencies of utilizing GPS to locate personnel, for example, failure of receiving or transmitting signals because of debilitation and false locating due to reflections.

A tracking system may be used for getting the exact location of an item or a person by using technologies such as GPS or radar system; however there are other means of tracking instead of getting exact location. For example, when tracking posts packages, a tracking system might not be able to get the exact location of them but clients still can get the location of posts packages in terms of country, city or building.

An indoor localization system is defined as a system that been used for tracking items or people within an indoor environment. There are many usages by implementing indoor localization system in our daily life. Manufacturing industry could make use of the localization system to locate their products so they can easily track the location of specific item from huge quantity of products in order to meet their customer's needs without wasting the time. Besides, an indoor localization system could be utilized by hospitals to track their medical equipment or patients within the building. This may help them to serve the patients promptly whenever there is an emergency condition happens.

Another usage of applying indoor localization system in daily life is to improve performance and security issue. This phenomenon could be realized when an employer can monitor the working motion of the employees in case to prevent them from loaf on the job and prevent unauthorized employees from entering the room that storing confidential or important materials. A part from this, one of the important functions of indoor localization system is to act as navigation tool in a complex building. For instance, whenever there is new employee or visitor arrives at a complex building, with the assistance of the localization system, they may get to their destination easily.

The localization of personnel consists of two parts, which is to pinpoint the personnel's location and allow for tracking and monitoring. In order for the personnel to be located, his data needs to be collected from the RFID readers within the building and transmit to the processing unit to analyse the current location of the personnel. The detection of personnel position will convenient for the supervision and searching process by the users especially when there is emergency situation happens.

Moreover, direction recognizer is used to determine the directionality of personnel's movement within the building. It will be associated with data buffer on FPGA which is used to store the unique IDs of personnel's tag to check the authorization status of personnel. Then with the designed algorithm, the movement directions of the personnel can be tracked according to the location ID collected following by assigning another action ID to carry out the corresponding action.

There are three major features of this project which are FPGA as main processing unit for the whole system, wireless connection among the RFID readers with processing unit and mobile Android tracking application with the integration of online database. Moreover, wireless connection is established among readers and processing units to minimize the wiring setup thus improve the system convenience. Last but not least, a mobile Android tracking application is designed and integrated with the localization system so the monitoring and searching can be easily done by client in terms of saving time and improve efficiency.

RELATED WORK

Fundamental of RFID

In this section, the fundamentals of RFID will be discussed in terms of its evolution, its systems, and its design challenges.

A. Advancement of RFID innovation

RFID is a moderately new innovation with the conviction by someone that its idea may have begun in military plane recognition during World War II and that it truly began to be competently grown for tracking and accessing utilization during 1980s [1]. The primary professional thought associated with RFID innovation was distributed by Harry Stockman in 1948 [2]. In like manner, the prime active RFID convention was unreal by Mario Cardullo in 1969. Since, Charles Walton unreal the early passive RFID structure in 1973. Arrest go off, exhaustive researches addressing RFID systems were refined in Los Alamos Catholic Laboratory (LANL) [2]. The initially individual owned RFID system was realized between 1980 to 1990. RFID regulations were popularized for the solid RFID technology between 1990-2000 [2].

B. Principle of RFID systems

RFID framework for the most part comprises of two sections: labels (tags) and readers. The coupling strategies between them are electromagnetic backscatter coupling and inductance coupling [3]. Electromagnetic backscatter coupling implies that RF flag created by the reader is sent to space through the radio wire as electromagnetic waves, which shape a perusing zone of the reader. The electronic tag in the region can get the working vitality from the reader radio wire and exchange the information data conveyed by the tag to the reader through the label radio wire.

The coupling technique is connected in the generally high recurrence or microwave recurrence scope of long-run radio recurrence recognizable proof framework. Inductive coupling is a sealed magnetic field coupling circuit between the reader/writer curl (essential) and the electronic label curl (auxiliary) [3]. Along these lines, this coupling technique is utilized as a part of the low recurrence of the close range contactless radio recurrence recognition framework.

Three types of systems can be concluded from the RFID system which are active RFID system, semi-passive RFID system and passive RFID system. In active RFID framework, labels can start the correspondence to the reader and the other way around [2]. This is because of an inside battery is installed in the active labels which energizes themselves and their RF correspondence hardware ceaselessly [4]. Consequently, even low-level indicators can be transmitted by readers and high-level indicators can be responded by the labels.

On the other hand, in a passive RFID framework, the passive labels are without battery and its work standards depend on retransmission or electromagnetic backscattering. Passive labels normally have smaller size and are less expensive than active labels, however with extremely restricted functionalities [4]. The last type of system is semi-passive RFID framework which its tags are also embedded with an inside battery in order to energize its in-house circuits steadily however the communication between the labels and the readers are same with the communication of passive RFID system [4]. In general, passive tags are chosen to be implemented within low cost systems despite of active tags.

C. Range of frequency

The scope of recurrence under which reader and tag works are also important to be concerned for implementing within applications. The RFID system can be classified into Low Frequency (LF), High Frequency (HF) and Ultra-High Frequency (UHF) ranges [5].

Low-frequency range

Low-Frequency framework has run 30-300 kHz and works in 125 kHz. This framework has a short read scope of 10 cm and the information read is slower contrasted with others. Yet, low- frequency framework can deal with metals or fluid surfaces [5]. The regions under which this framework is being utilized such as to get animals being tracked. The gauges are ISO 14223 and ISO/IEC 18000-2 which is utilized for creature following frameworks [5]. Despite the fact that it is being utilized as a part of a few applications, by and large, it is not acknowledged at a worldwide level.

D. High-frequency range

High-Frequency has a scope of 3-30 MHz and works in 13.56 MHz. This framework has a read scope of 10cm to 1m and this framework encounter tolerable reactivity to obstruction [5]. Instalments, ticketing and information exchanges are a few applications which utilize High-Frequency framework. The gauges are ISO 15693 for tracking things, ISO/IEC 14443 for MIFARE innovation and JIS X 6319-4 for Smart Card System [5].

E. Ultra high-frequency range

Ultra High Frequency has a scope of 300MHz to 3 GHz and it works in 900 to 915 MHz [5]. The read scope of this framework can go up to 12 meters and information exchange is the fastest if contrasted with the other two. This framework has a high affectability to intervention however work is going ahead to make antenna, reader and the tag can work even in terrible

situations [5]. Remote gadget design, retail stock administration and pharmaceutical against falsifying are the applications which utilize this innovation. This framework is profoundly proficient and scope of the market is developing fast. The norm is ECP global Gen2 (ISO 18000-6C) UHF standard. The UHF is 60 times more effective than HF innovation in performing RFID activity.

Study of IoT based on RFID technology

According to [6], Internet of Things is the third influx of worldwide information commerce with the involvement of computer, the Internet and mobile communication network. Four main application innovations of IoT have been proposed by the International Telecommunication Union which are RFID innovation, sensor innovation, smart innovation and Nano innovation. IoT can be specified to an immense network built by the Internet and variety of information sensing devices, for instances, RFID, infrared (IR) sensor, global positioning system (GPS) and laser scanner [6].

The objective of having IoT concept is to link all the devices or system with Internet in order to track, determine, localize, supervise things or personnel in real time and naturally activate the related occurrence [6]. The idea of IoT alters the conventional thought which isolates the physical frameworks for examples airplane terminals, streets, and structures from IT foundations for instance server farm, PCs, and broadband. Notwithstanding, fortified cement and cable will be unified with chips and broadband into integrated foundations in the generation of IoT [6].

Massachusetts Institute of Technology which founded the Auto-ID center has proposed the idea of IoT, "everything can be connected through the network" in 1999 [6]. IoT is interpreted and defined into two explanations, (1) the basis and groundwork of IoT yet is the Internet in addition with the development and growth of Internet, (2) IoT user has spread into information transfer and communication among any things. On the other hand, IoT can be defined precisely as all the things are linked together with Internet through data collecting devices for purpose of achieving smart recognition and administration.

A. Implication and architecture of IoT

IoT links everything and Internet with data collecting gadgets as admitted rule of conduct for data swapping and communication. A huge amount of data can be interpreted by utilizing leading cloud computing innovation and super computers [6]. These innovations can be used to assist client in decision making for accomplishing smart recognition, localization, tracking, supervision and administration.

The significance and principle of IoT is to provide new functions to network to accomplish conformity and communication among people and things, determine the regular response and create suitable choices. Figure-1 depicts the architecture of IoT consisting of collection control layer, access layer, support network, application control layer and clients [6].

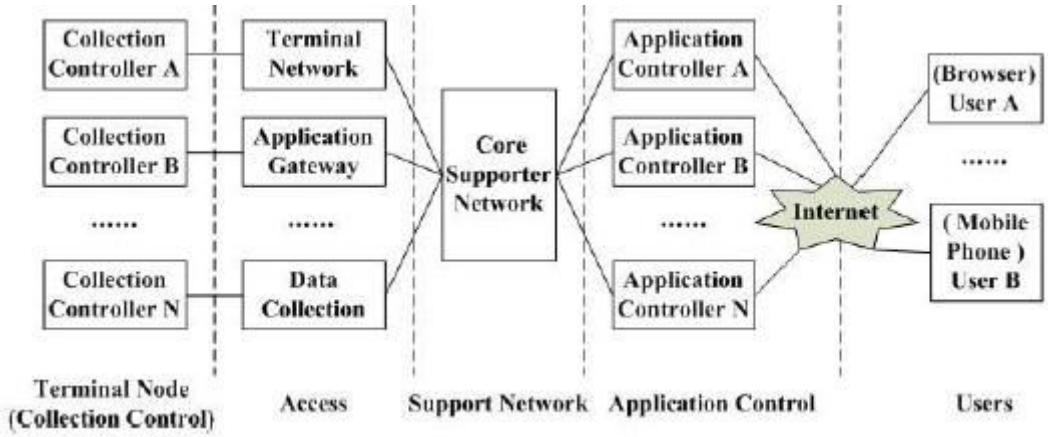

Figure-1. Architecture of IoT system[7].

The structures and the roles of each layer or component are discussed by following [7].

a) **Collection control layer:** It is also known as terminal node, which the network established by variety of sensors and RFID is utilized for recognition and information swapping.

b) **Access layer:** It is also known as transmission layer either can be equipped with wires or no wires of network design.

c) **Support network:** The fundamental network comprised of computer network and communication network, which links the data input side and the output application side.

d) Application control layer: Various types of applications that build up on the fundamental of data are controlled by this layer.

e) Clients: Ascertaining the network via browsers on computers or movable devices can be done by clients.

B. Design challenge of Internet of Things (IoT)

Nowadays, countries from all over the world have begun their own networking research and carry out some development, yet, some essential difficulties need to be resolved. There are two situations needs to be signified, which are technical field of deficiency and networking circumstance issue. As a technical opinion, although today's society is starting to utilize various types of sensors in obtaining variety of data and information, there is still lack of developed and excellent research, study and application of the sensor networks field [8].

IoT is a newly arise approach where the structure of its extrinsic circumstance is still not set up, the quantity and quality of utilization has not achieved the scope, and the real conditions does not meet the interest of evolving networking innovation. A part from this, the networking principle is required to be solved immediately due to there are countries compete for the discourse right on the Internet of Things so the intellectual property rights can be possessed by the one who retains the Internet standard [8].

Performance parameters of indoor localization system

In order to design and build up an effective localization system for indoor environment, there are some performance criteria stated following need to be correlated with the system [9].

a) Accuracy: The degree of freedom from error where can be obtained through the difference between the estimated location and the actual location of the personnel. The greater the accuracy, the superior the framework is.

b) Precision: The likelihood of the accurate location being estimated.

c) Latency: The time taken between sending a location requisition and retrieving the location data.

d) Energy Consumption: The lower the energy being consumed by a mobile node, the longer the lifespan of the device.

e) Cost: The cost of essential base, installation of facilities, conservation and preservation is depended on the groundwork of an indoor localization system.

f) Complexity: Intricacy of an indoor localization system can be affected by the implementation of hardware, software and the manipulate element. An integrated computing composition can build up the less complex indoor localization system.

g) Coverage: The border limitation where the localization system can respond in evaluating the location data.

h) Stability: Stability is defined as the robustness of the localization system in dealing with the faults during execution and operating well even though there are signals absent or never seen previously.

Real-Time Locating Systems (RTLSs) by using active RFID technology and BLE technology

The transit of individuals and items through high-activity business areas and work fields is a troublesome thing to screen outwardly. Many of the employers or companies have paid a lot for installing the equipment such as CCTV or access control system and concerned about the security problem in order to track their employees or monitor the flow of their items. Thus, an impressive resolution in solving the existing tracking problem is kept seeking by those employers. A method to supervise the location and transit of personnel or item in addition enhance the accessing to restricted area by unauthorized personnel and show warning when an item is being taken from store can be realized through real-time locating systems (RTLSs) [9].

A. The techniques used in a RTLSs to track personnel

Active IoT RFID and Bluetooth low-energy (BLE) beacon innovation are being utilized to track identification tags that have been assigned to the personnel [9]. The tags may be outfitted with additional characteristic for instances panic buttons and motion sensors [9] and rechargeable. The receivers are set up at those crucial areas around the working environment for examples entrances, corridors and parking lots so the receivers can track and collect the information whenever someone pass by the places. Besides, rechargeable, panic button-equipped ID badges with integration of ultra-wideband (UWB) active RFID innovation is distributed to personnel.

Once the framework is done installed, a hidden connected chain is being established which can track the position of a tag/badge within a range of below one meter. The information collected by the receivers will be transmitted to programming application in order to define the collected byte data into user-friendly language or displays and store them for subsequent study. Either computer or mobile device can be used to achieve the tracking software by Litum IoT [9] for the purpose of supervise the personnel's activities in real time.

Litum's tracking software shows each identification position by superimposing on a building plan, and each identification is defined as a moving point with some essential data being shown up above it, for example, the worker's name. This enables clients to know

where the personnel are found and in which bearing they are shifting. The software is allowed to assemble automated warns, construct reports, refine data presentation, refine badge data, track personnel hours and enhance access control system [9].

BLE beacon innovation is identical to the current Bluetooth technology used on the mobile phones or else Bluetooth-enabled gadget. In this innovation, short-link radio transmission is used instead of wired connection in dispatching data thus high data transmission rate is achieved.

B. Benefits and drawbacks

The implementation of RTLSs from Litum IoT is beneficial in term of cost saving. The phenomenon is due to the enhancement of security aspect and safety aspect when the panic button designed by Litum IoT on the badge is being used. Emergency signal is prompted when someone that may face critical problems such as accident and crime pressed the panic button, the employer can manage to overcome the problems on time or provide help promptly, then the extra compensation cost for their employees can be saved since the problem is solved beforehand.

Furthermore, an adequately controlled tracking framework can enable employees to feel more secure at work and enable them to complete their work consistently with less anxiety. This prompts enhancements in work fulfilment and worker wellbeing and general financial advantages of prompting to the accelerated manufacturing process and delivery times.

Whenever there is a benefit, in contrast, there will be a drawback. The disadvantage of the technology is that client needs to buy software announced by the manufacturer in order to use the tracking system. Besides, client cannot improve the system by themselves anytime in future but need to depend on the software update by the manufacturer. However, in my project, FPGA is used in the localization and tracking system which the hardware architecture is built based on the application needs instead of depends on others. Future improvement can be achieved easily when the hardware architecture is done by own.

In addition, although the technology with the software provided can be used to display the location of personnel on building plan through any device, yet this is not efficient as client is hard to search for a person if there are a number of people exist at each floor of the building. In contrast, an Android application is created in my project, and it can function to search which floor is the specific personnel locates, therefore client can easily know the floor number of the personnel exist.

SUGGESTED METHODOLOGY

A. Overall flow of indoor localization system

First of all, personnel need to scan their tag at main gate of the building respectively before entering the building. The scanned tag's ID together with the location ID is stored in Input Data Buffer as temporary storage for later validation use. Then, these unique IDs are compared with the pre-stored personnel database built in the on-chip memory of FPGA. If validation process is success, a pre-determined action ID is transmitted and the updated information is sent to online database for status update and display later. The status of the ID is set as "Present" in main building and the current stayed floor is set as "1" when client enters the building while the status of the ID is set as "Absent" in main building and the current stayed floor is set as "Absent" to indicate the client is now exit the building.

After that, when the person would to enter the first floor's meeting room, his tag is again need to be scanned before entering the office. Once again, the status of the ID is set as "Present" in meeting room and the current stayed floor is still set as "1" when client enters the meeting room while the status of the ID is set as "Absent" in meeting room and the current stayed floor is set as "1" to indicate the client is now exit the room but still remains in first floor. When he would like to go up second floor by stairs, he is also required to scan his tag at the entrance in order to use the stairs, now his ID's status at first floor will change to be "Absent" and "Present" at second floor for the means of entering second floor. There will be same procedure for entering or leaving second floor's self-working room and leaving second floor.

Data signals are read from the readers and sent to DE1-SoC board wirelessly using WiFi module, NodeMCU V3. The data retrieved from signals is stored into the Input Data Buffer for further processing to get the location status being updated on time. The data that stored in Input Data Buffer is the concatenation of location ID and personnel's unique ID. A comparator is designed to validate the data received with the pre-stored memory data as only location status of validated unique ID can be updated in online database. The updated location status that is indicated by using a unique action ID is stored into Output Data Buffer in order to pass through uart to upload into online database and keep for later displaying purpose on the Android mobile application.

The location status is updated in online database under personnel's unique ID together with the personnel's information. An Android application is designed to access the database for data retrieving and location tracking by any user. When user tries to key in level number, the number of person exist at the level and their names are displayed on smartphone. On the other hand, if user direct inputs the name or employee ID of person that would like to be tracked, the Android application is showing the current location status of the person directly.

The internal clock frequency of the system is enhanced and stabilized to improve the processing power of the system. In order to realize the purpose, Phase Locked Loop is used and will be discussed in coming section. Figure-2 shows the layout design of the RFID readers allocation while Figure-3.depicts the overall flow of the indoor localization system in form of finite state machine

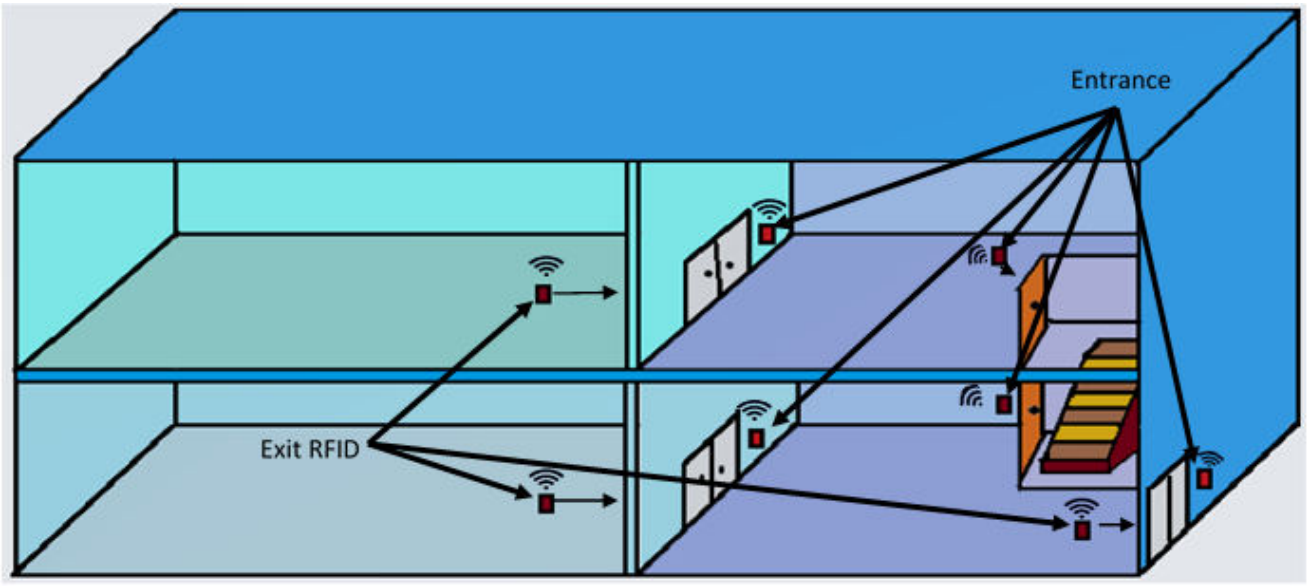

Figure-2. Layout design of RFID readers allocation within building.

FMR - First Floor's Meeting Room
FF - First Floor
SSR - Second Floor's Self-working Room
SF - Second Floor

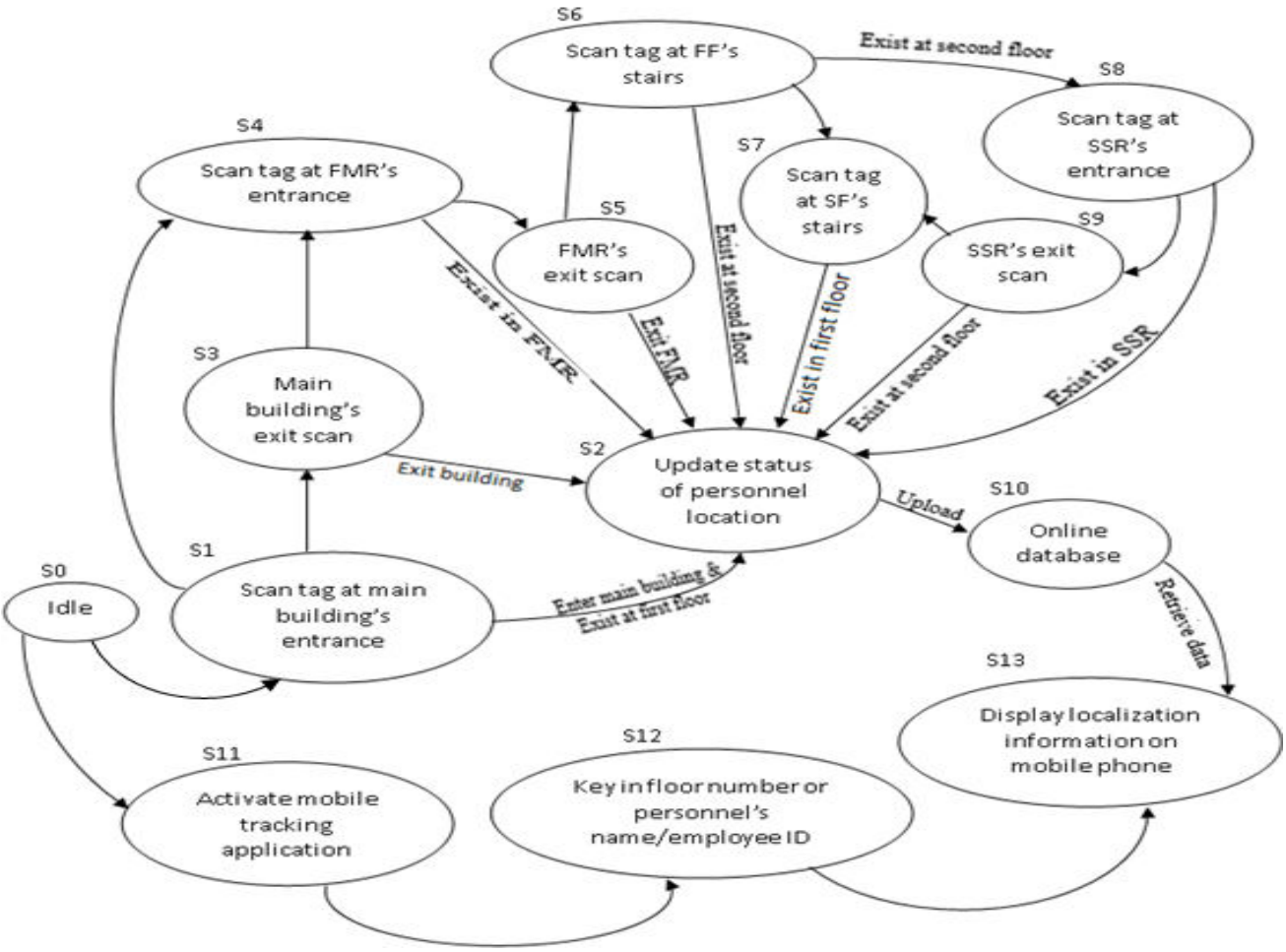

Figure-Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.** Overall flow of indoor localization system in form of finite state machine.

Component testing

In this project, there are two types of component being used, which are RFID reader and tag and WiFi module, NodeMCU V3. Each component has been tested of its functionality and capability. Each type of component is tested until the result is satisfied before buying in large quantity.

A. RFID Reader and tags

The RFID reader and tag used for this project is RFID MFRC522 reader, RC522 card and RC522 key as shown in Figure-3.1. The RC522 reader is connected to NodeMCU V3 through the pin assignment of SDA pin, SCK pin, RST pin, GND pin, VCC pin, MOSI pin and MISO pin of the reader. At this stage, NodeMCU is only functioned as an interface to build the firmware of the RC522 reader and test it. It is not connected to Internet in this testing. An example Arduino coding is get from online development platform, GitHub to upload onto ESP8266 WiFi module through Arduino IDE 1.8.1 in order to read/write the RC522 card.

The read range of the reader is tested by adjusting the RC522 card/key from the closest to the reader and moves out little by little until the card/key cannot be read by the reader. The read range of the reader is tested from front, back, top, left side and right side of the reader. Besides, the capability of the reader to read multiple cards/keys at one time is evaluated. During a card is read, multiple of other cards/keys are added one by one in order to test the minimum number of cards/keys can be read by the reader at one time. Furthermore, the card/key is tested on the ability to be written with the data required.

The part of the testing is shown in Figure-4 and Figure-5. After the result is satisfied, the RFID reader and tags are decided to be used in this project.

Figure-4. Testing on the read range of the reader.

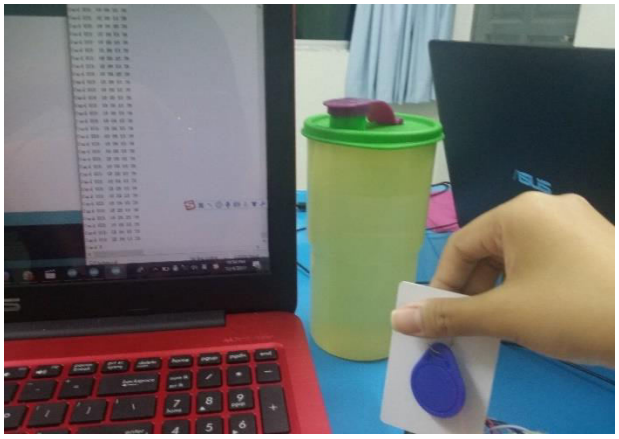

Figure-5. Testing on the minimum number of cards that can read at same time.

B. NodeMCU V3 WiFimodule

The NodeMCU V3 WiFi module is tested on its ability to connect to the Internet. The example Arduino coding is also get from GitHub and modified according to requirement then uploaded onto the NodeMCU V3 WiFi module to test whether the WiFi module can establish connection with the Internet. Arduino IDE 1.8.1 is the only software platform to be used in this testing stage and connects with WiFi module through Universal Serial Bus (USB) port. The coverage range of the WiFi module is also be tested in approximation condition.

Configuration of wireless connection among multiple WiFi modules

As discussed in previous section, the RFID and WiFi module are tested individually to identify their parameters respectively. Since, wireless data transmission between RFID readers and DE1-SoC FPGA board is needed, therefore involves the connection setup among multiple WiFi modules. In order to build the connection, server-client setup is configured. There are eight WiFi modules act as client which is connected with each RFID reader respectively. Besides, a WiFi module is coded to act as access point (server) to allow the clients WiFi modules connect to it for data transmission purpose. The clients collect the data from RFID readers then connect to the access point created and send out the data to the server side through the access point and "*client.print*" command. After that, at the server side, it always checks whether there is a client connects to it so it can build up the connection once a client is connected. After a client is connected to the access point, "*client.readStringUntil("\r")*" command is used to catch the data sends by client. Some part of the code in server side and client side are depicted in Figure 3.6 and Figure-7 respectively as shown in below.

```
WiFiClient client2 = server.available();
if (!client2.connected()){
    return;
}
if(count!=1){
    rfidCode = client2.readStringUntil('\r');
    Serial.print(rfidCode);
```

Figure-6. Code of receiving data from client side.

```
String content1 = "a" + content;
Serial.println("UID : "+ content1);
client1.connect(host, httpPort);
client1.print(content1+"\r");
delay(250);
```

Figure-7. Code of sending data to the server side.

Integration of processing unit

The main processing unit is the main module designed for this system. The functions of the processing unit are to collect the signals and data read from every RFID reader, identify the location of personnel, and send out the location status to online database for Android application use later. Time synchronization, baud rate, frequency and speed will be the main factors to be concerned in designing the processing unit. In order to design a processing unit, multiple modules are designed and implemented. In previous section, UART module which is used for serial transmission to collect/send data from/to WiFi module has been discussed, thus in the following sub-sections, the remaining modules are discussed.

A. Input data buffer

The data that is received by the processing unit is a three byte data however only one byte data can be received per serial transmission using the UART module. Therefore, an input data buffer is designed to collect all three byte data before sending to the next module to be processed. Every single data bit is received at every clock cycle according to the serial transmission principle, which means that every 8 bits data received, the data valid signal is triggered until the last 8 bits data received, the total 24 bits data is now passed to the next stage for validation and analysis purpose. Part of the RTL view of the data buffer is shown in Figure-8.

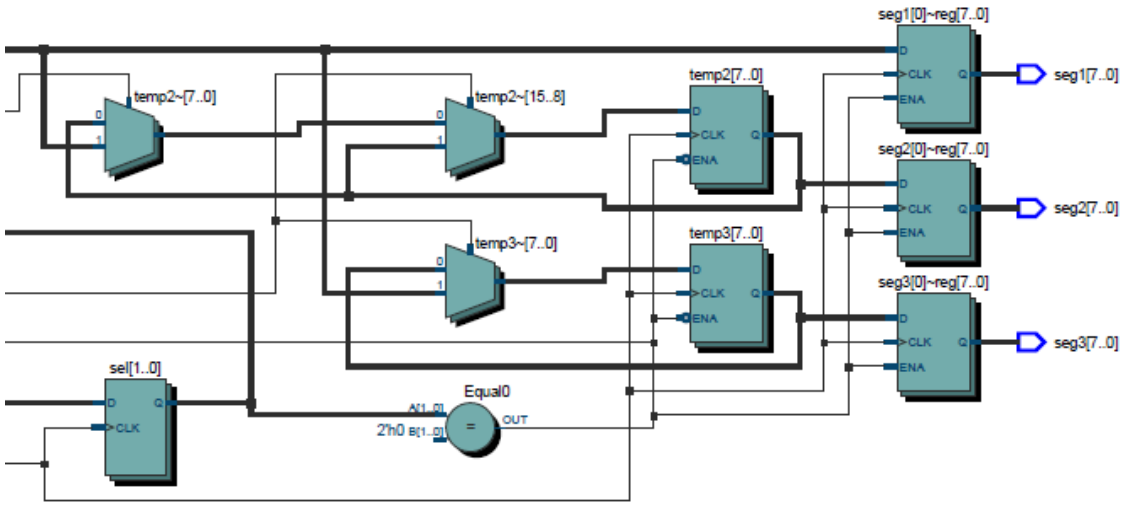

Figure-8. Part of RTL view of data buffer.

B. Read/Write address controller

Address controller is designed to control read/write address of on-chip memory to retrieve or write the desired data from/to the memory. For read address controller, there is a counter created to count on every logic high clock cycle, then the count is used as the address to be input into the memory. Logic low is set for write enable when the retrieve data process is required. Figure-9 shows the RTL view of the read address controller.

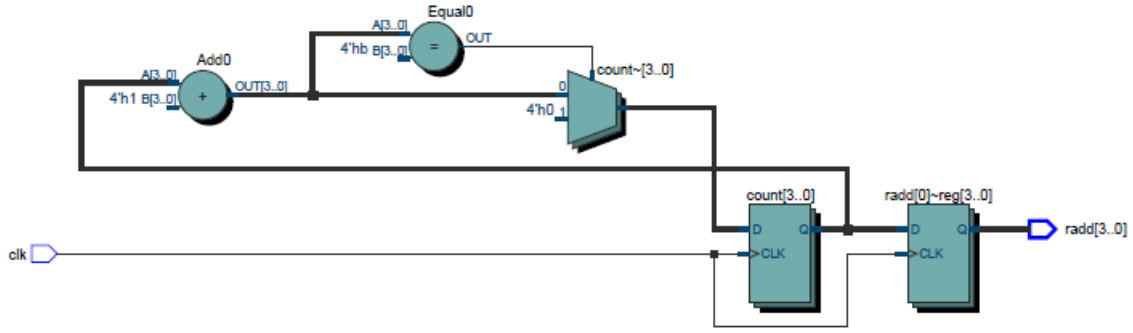

Figure-9. RTL view of read address controller.

On the other hand, there is still a counter to count on the value to be used for write address; however there is a condition to check the memory content which is work along with read address controller. If the memory content is null value and new data is available, then the write enable is set as logic high to and the new data is written into the memory location of the write address. Part of the RTL view of write address controller is shown as Figure-10.

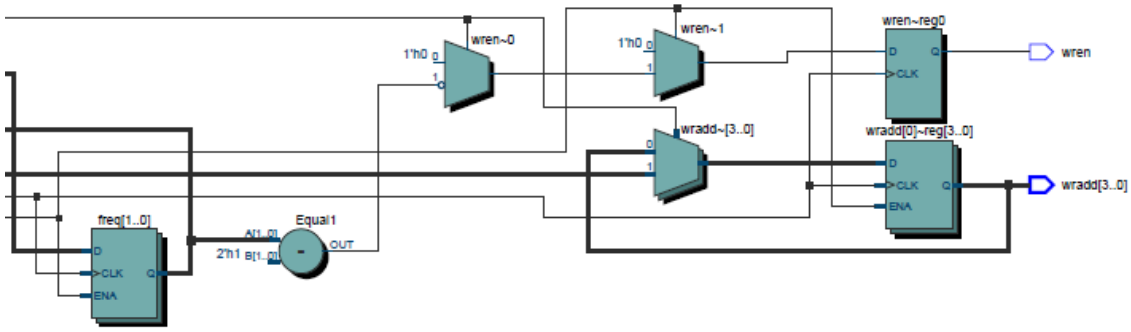

Figure-10. Part of RTL view of write address controller.

C. Comparator

Comparator is one of the important module that is implemented in the processing unit. The data received from UART module is validated by using the data retrieved from memory in order to validate the identity of personnel. Therefore, only the personnel that has his tag's unique ID stored in memory can update his status of location. Next, a byte from the three byte of collected data is the location ID which is used to analysing the location information of the personnel.

After the result is obtained, an action ID is ready to be sent back to the WiFi module for calling the updating commands through the serial communication. Since the feedback data is ready, the data send signal is triggered to allow the transmitting process to be happen. During the transmission, busy signal is triggered to block the next transmission unless the current transmission process is finished. Figure-11 depicts part of the RTL view of the comparator module.

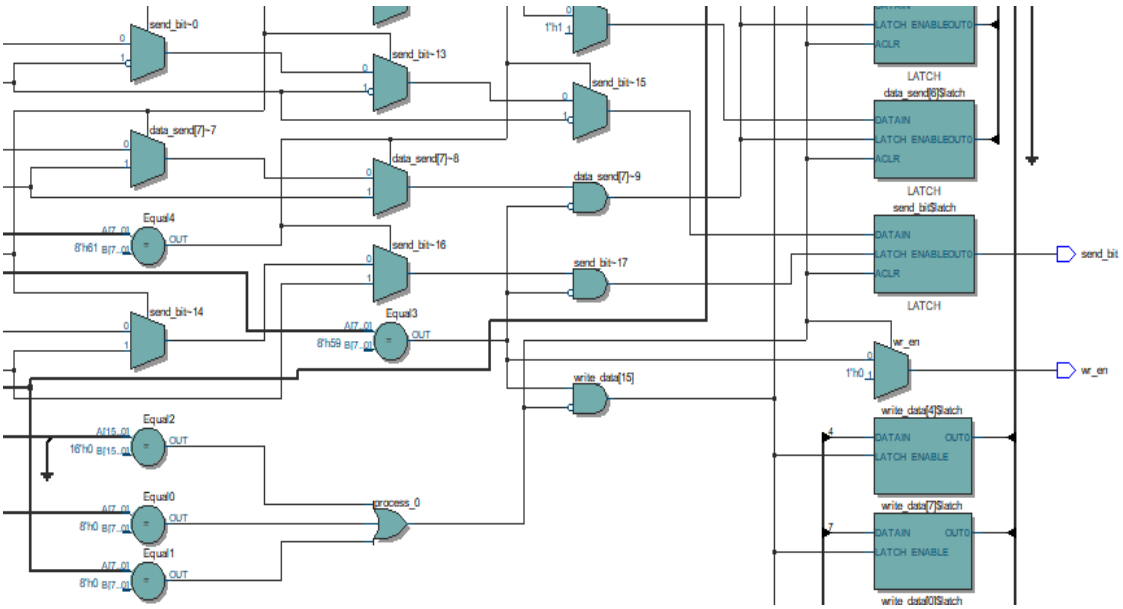

Figure-11. Part of RTL view of comparator module.

D. Phase-Locked Loop (PLL)

PLL is utilized in this project to improve the performance of the system. It is used to produce stable clock frequency compared to the clock frequency that generated by crystal oscillator. By having this feature, the processing power of the system is able to be improved which may help in reducing system latency from the FPGA side.

E. Top level of processing unit and its RTL view

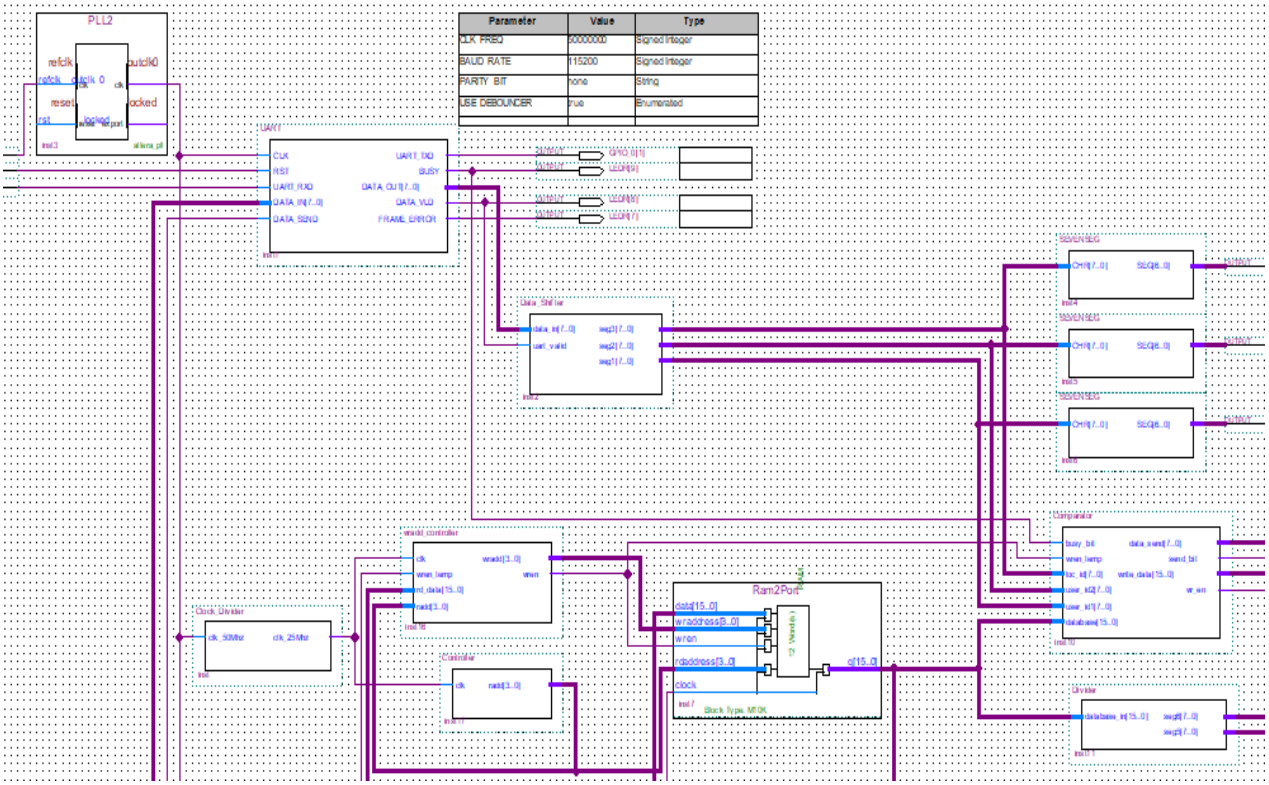

Figure-12. Part of the top level design of the processing unit.

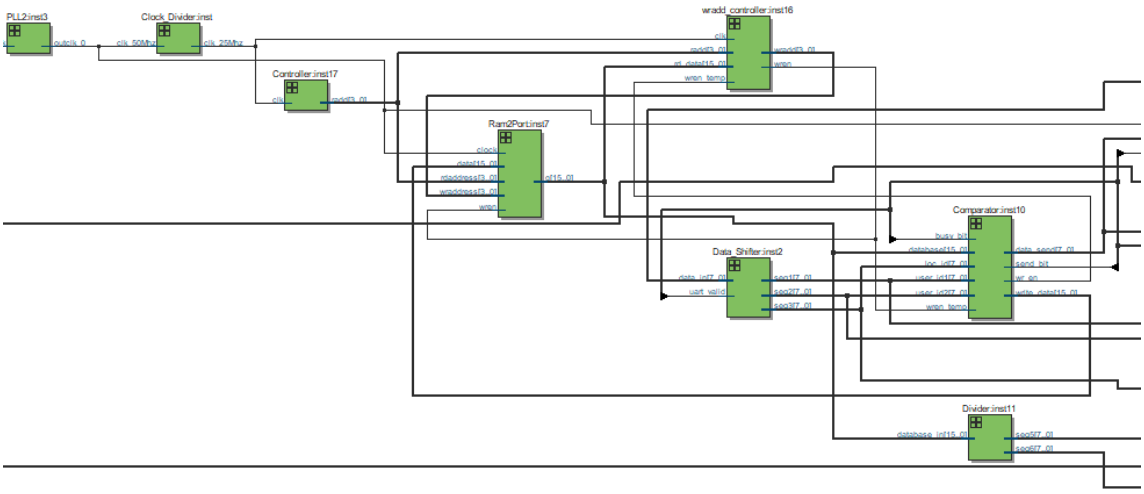

Figure-13. Part of the RTL view of processing unit.

RESULT

In the early stage of project development, the functionality and limitation of RFID readers and tags are tested. With the firmware built, the unique ID of the RFID tag is able to be retrieved as shown in Figure-14. The total eight RFID readers have been tested and able to retrieve the unique ID of the tags. Among of the thirteen RFID tags that have been tested, there are two of them are not able to function which means that their unique IDs are not able to be retrieved.

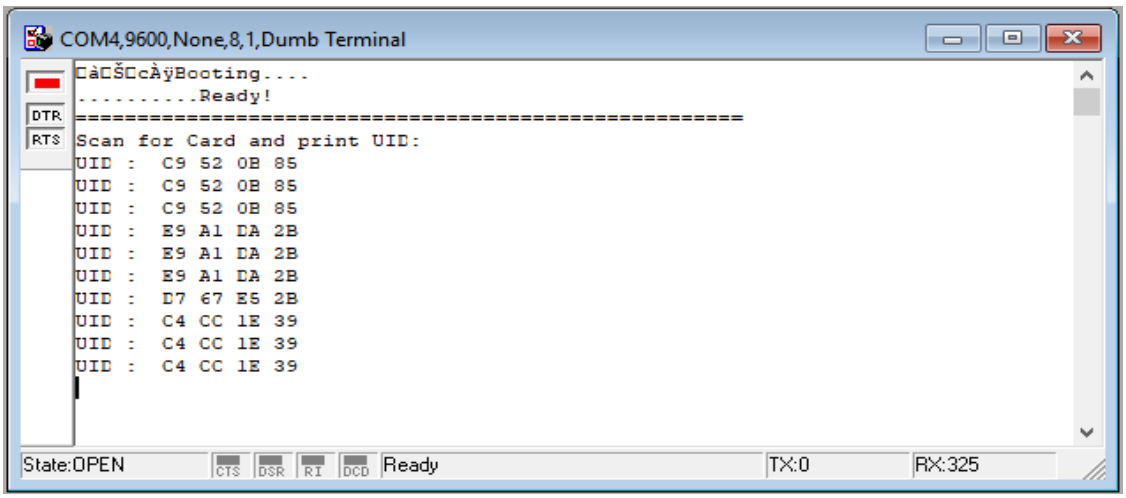

Figure-14. The unique ID of different RFID tags is able to be retrieved by the readers.

A part from this, the NodeMCUWiFi module has also being tested to connect to the WiFi network. The waiting signal "…" is printed when the WiFi module has not connected to the network while a sentence is displayed to indicate the WiFi module has successfully connected to the network. The testing result is shown as Figure-15.

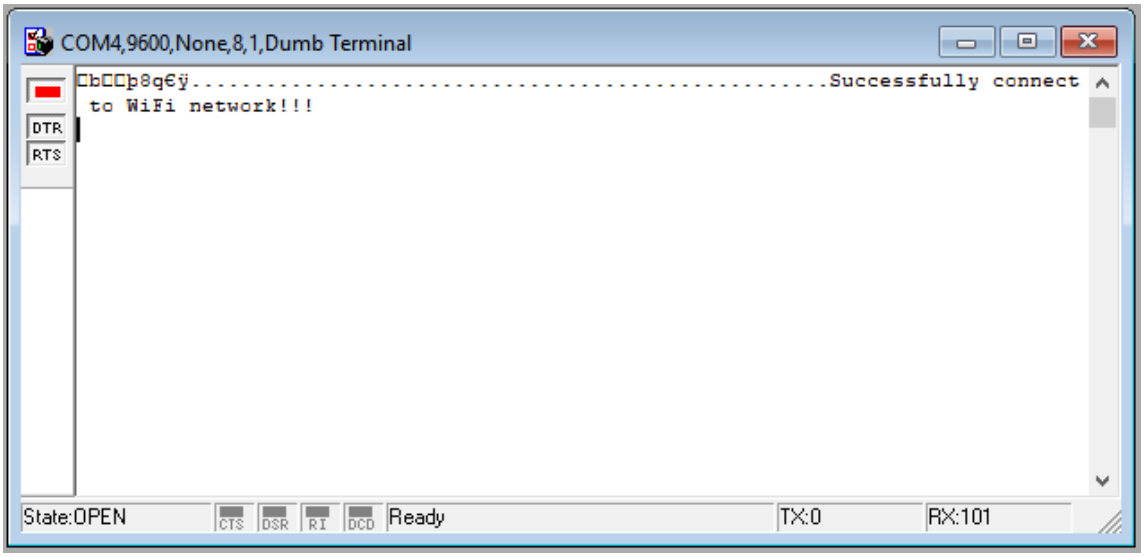

Figure-15. NodeMCUWiFi module has successfully connected to the WiFi network.

Result of processing the data collected in FPGA board

Throughout the data processing process, seven segments and LEDs on the FPGA board are temporarily used to show the output of the process. Firstly, the content of every memory location designed in FPGA is retrieved and shown on seven segment displays (HEX4, HEX3) as two characters of pre-stored unique ID of clients at every clock cycle. The first character is displayed on seven segment, HEX4 while the second character is displayed on seven segment, HEX3. The result can be seen from Figure-16. below.

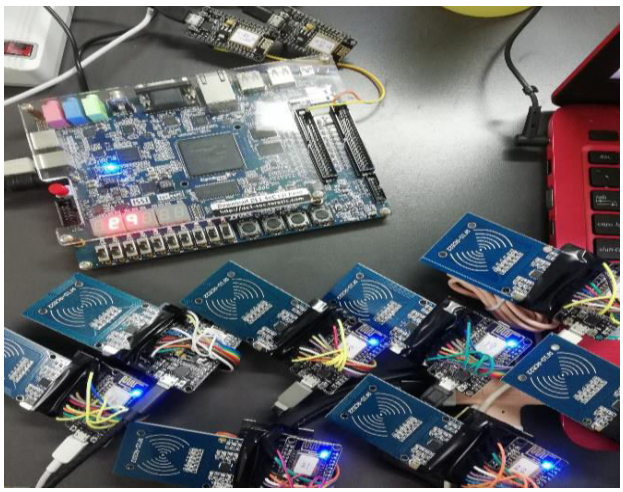

Figure-16. The content of every memory location is shown at seven segment display (HEX4 and HEX3).

When a client scans tag at any reader, the location ID of the reader is collected together with the unique ID of his/her tag and sent to the processing unit which can be seen on the seven segment displays on FPGA board (HEX2, HEX1, HEX0). From the Figure-4.4, location ID is displayed on the seven segment, HEX2, first character of unique ID is displayed on seven segments, HEX1 and the second character of unique ID is displayed on seven segment, HEX0. The detailed display is shown in Figure-17.

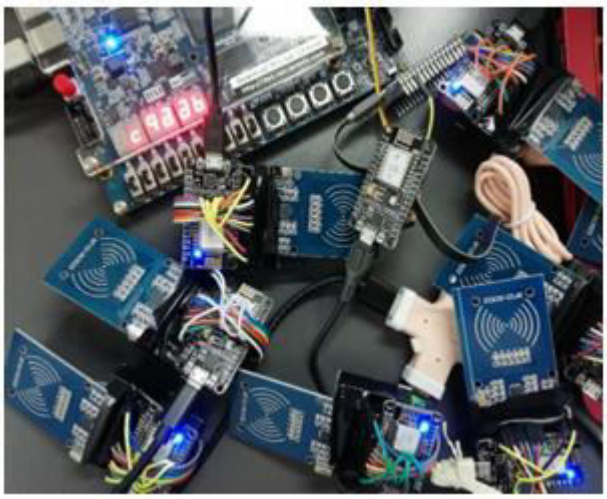

Figure-17. Data retrieved from RFID reader is shown on seven segment displays (HEX2, HEX1, HEX0).

Next, the collected data is compared with the pre-stored data for validation purpose. Once the validation success, the collected location ID is analysed to compute the corresponding action ID for the following process. The action ID is displayed on the seven segment, HEX5 and the description for every action ID is tabulated in Table-1. When the action ID is being transmitted, the busy signal which is indicated by LEDR9 is turned on to block new transmission until the current transmission is finished. The clearer concept can be obtained through the Figure-18.

Table-1. Action ID's description.

Action ID	Description
A	Present in main buildingPresent at first floor
B	Absent in main buildingAbsent at first floor
C	Present in meeting roomPresent at first floor
D	Absent in meeting roomPresent at first floor
E	Present at second floor
F	Present at first floor
G	Present in self-working roomPresent at second floor
H	Absent in self-working roomPresent at second floor

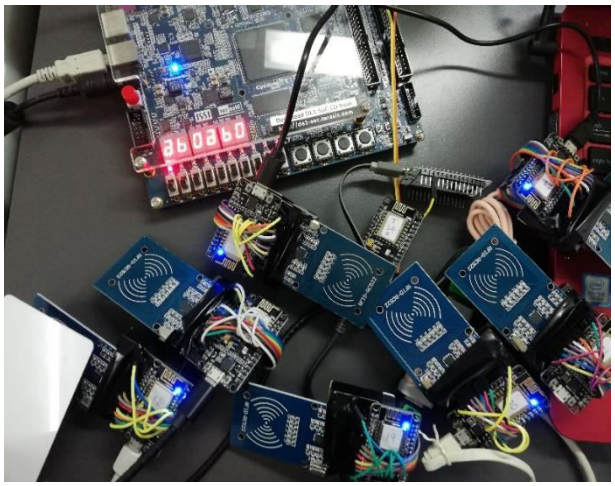

Figure-18. Action ID on seven segment display HEX5 produced after data processing and analysing is sent out with the "busy" LED turned on.

A part from these, from the compilation report of the processing unit as shown in Figure-19, the system has used up 188 logic elements and 143 registers of on chip resources.

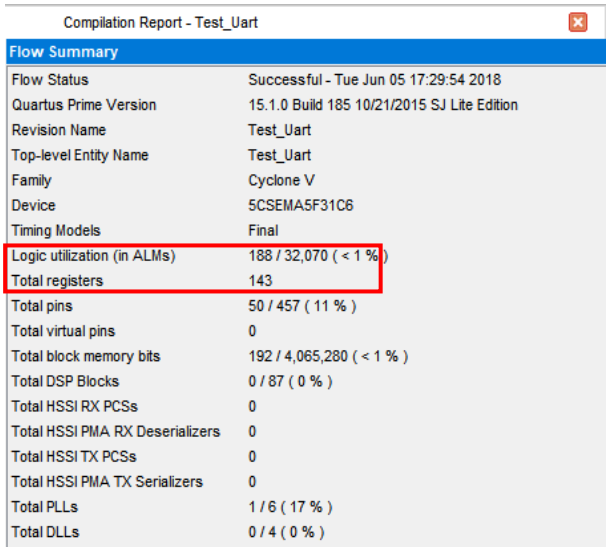

Figure-19. Compilation report of processing unit on FPGA.

Result of updating location status in online firebase

The part of initial look of the online database is shown as Figure-20. In the database, there are row to collect the unique ID sent out from RFID readers, row to indicate the availability of new registered client from mobile application and list of clients with his/her information such as name, employee ID, department, unique ID, location status and last updated time. The detailed indication of the rows in database is described in Table-2.

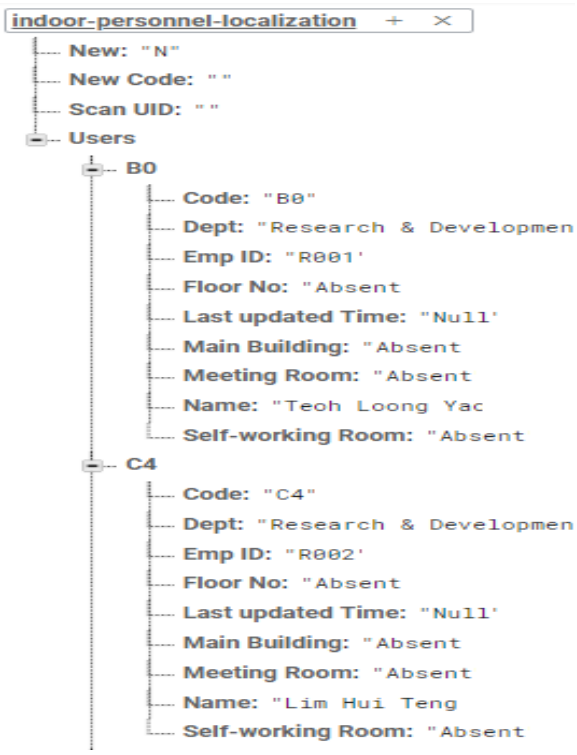

Figure-20. Initial look of part of online database.

Table-2. Description of rows in online database.

Row name	Description
New	To indicate the availability of the new registered mobile applicant. Y = New registered applicant is available N = New registered applicant is not available
New code	The unique ID of the new registered applicant.
Scan ID	The unique ID that has been retrieved when client scan his/her tag at RFID readers.
Users	List of client's unique ID. There are several rows of client's information and location status under the unique ID.
Code	Unique ID of a client.
Dept	Department of a client.
Emp ID	Employee ID of a client.
Floor no.	Floor number of a client exist. Absent = Does not exist in the building 1st = Exist at first floor 2nd = Exist at second floor
Last updated time	The time of location status of a client being last updated.
Main building	The location status of a client in main building. Present = Exist in main building/Enter into main building Absent = Exit from main building/Leave from main building
Meeting room	The location status of a client in first floor's meeting room. Present = Exist in meeting room/Enter into meeting room Absent = Exit from meeting room/Leave from meeting room
Name	Name of a client
Self-working room	The location status of a client in self-working room. Present = Exist in self-working room/Enter into self-working room Absent = Exit from self-working room/Leave from self-working room

Then, for an example condition, when client scan his/her tag, the unique ID is displayed on the "Scan UID" row in the database as shown in Figure-21.

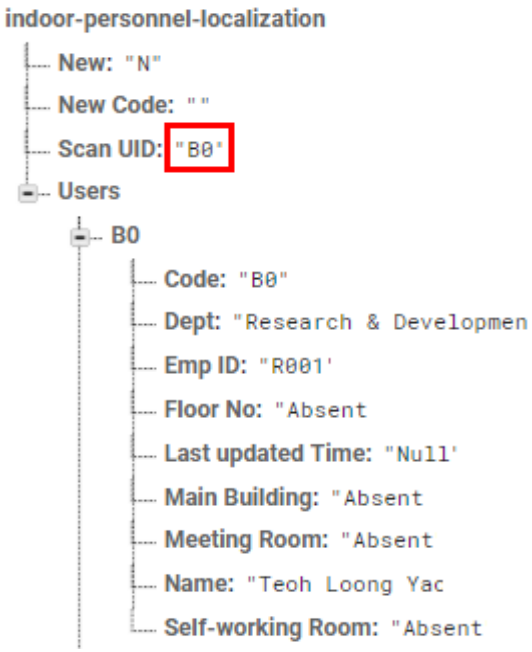

Figure-21. The unique ID retrieved is displayed in the row of "Scan UID".

After that, the action ID that is computed is used to initialise the commands which are used to update the location status in the database. For instance, if the tag is scanned at the main building entrance, then the update is occurred at the row of "Main Building", "Floor No" and "Last updated Time" as shown in Figure-22. below.

Figure-22. Database update when scan tag at main building's entrance.

A part from this, there is another example condition where a new client is registered through the mobile application. Therefore, whenever there is new registered client, the row of "New Code" in the database is set with the unique ID of the new client and the row of "New" is set as "Y" to indicate new client available and send signal to FPGA board for updating the memory in the FPGA board as shown in Figure-23. Moreover, the information of the new registered client is added into the online database. Then, the new registered client's unique ID is stored in the empty memory location and available for next time validation process. Figure-24show the changes on FPGA board.

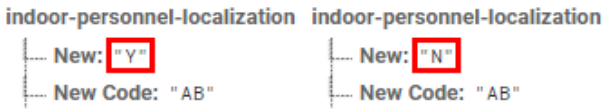

Figure-23. Availability of new registered client (Y = store unique ID into FPGA memory, N = finish store new unique ID).

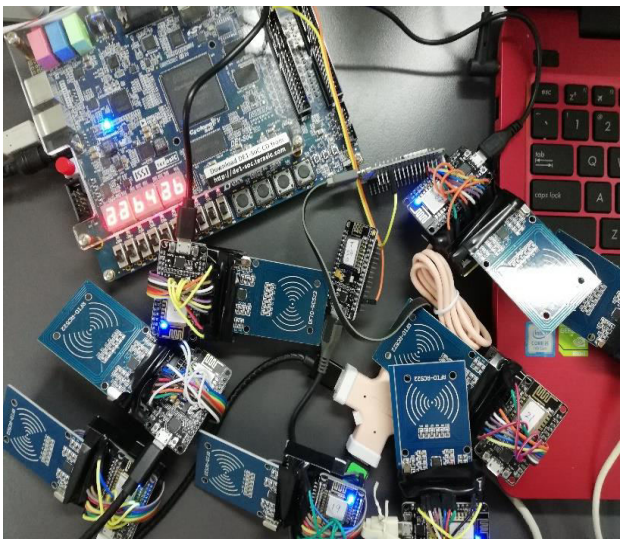

Figure-24. New registered client's unique ID is stored into FPGA empty memory location.

Prototype interface

The prototype is built as a two-storey building where there is a room at each floor. The RFID readers are mounted at every entrance and exit of the building. The procedure of building the prototype is shown in following figures.

Figure-25. Sketch prototype layout on wood pieces and cut them down.

Figure-26. Building the furniture models

Figure-27. Build up the main prototype.

Figure-28. Paint the furniture.

Figure-29. Set up all the furniture in the prototype.

Difficulties faced and its causes or solutions

One of the difficulties is serial transmission that has been built between WiFi module and FPGA board can only transfer one byte data per transmission. Therefore, input data buffer has been designed in the processing unit in order to collect all three byte data before processing the data. Besides, since there is a function to add new client's unique ID into the memory on the FPGA board, the address generators to control the read/write address are correlated. During designing the address controllers, the new unique ID has been added into wrong memory location which is already had the pre-stored data due to wrong logic is being implemented. At last, correct address controllers are successfully created after re-design the logic.

Moreover, there is an issue raised where the WiFi module kept rebooting when "Serial.readString()" function and "client.connected()" function works together in a firmware. Thus, in order to solve the problem, the two functions are worked separately in different firmware by using two WiFi modules. Furthermore, during updating status in online database, the last updated time is being recorded. However, the time snapshot is only approximation but not the exact time. It might due to the latency of retrieving time slice from the NTP time server. Since the issue is minor, thus it can be negligible.

CONCLUSIONS

The Indoor Personnel Tracking System had been successfully designed and implemented by integrating DE1-SoC board, RFID readers and tags, WiFi modules and Android application. The result of this system is fulfilled the project's requirements and a good performance is achieved. Besides, the knowledge of NodeMCUWiFi module, online database and Android application had also been increased.

In a nut shell, the four objectives stated had been achieved in this project with the indoor personnel tracking system able to track personnel within the building and directionality of personnel in term of rooms or floor. Moreover, the system processing power had been improved with decreased design cost due to reconfigurable characteristic of FPGA.

ACKNOWLEDGEMENT

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