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Development of Prototype Smart Door System With IoT Application

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Abstract: In this paper, the design of prototype Smart Door System with IoT Application which act as a digital door system is discussed. This paper presents the idea of controlling the lock, detecting a motion, and monitoring by live camera via a mobile application. This study is conducted to propose an enhancement to the traditional door system by utilizing the Internet of Things (IoT) technology. The bridge that we built between hardware and Internet is what we call IoT, and in this paper, Blynk application is used as the bridge for IoT.

Keywords: Smart Door, IoT, Mobile Application

1. Introduction

Over the decade, wireless communication has took the place in developing a better home automation system [1]. Conventional door system has been lacking in the safety area, as the keys can be easily duplicated. Thus, digital door lock system is one of the essential system that need to be installed in our house in order to have a more secure environment [2] and [3].

With IoT element applied, the digital system can be really beneficial, since we can control and monitor the system with our smartphone or any device [4 - 6]. This feature could be really helpful at the moment of our carelessness, in case we forgot to lock our door when stepping out [7]. The technologies around us are indeed getting smarter each day. However, in order to make them efficient, we need to link them up in a dynamic environment which create their own inter-network that brings to machine-to-machine communication [8]. The major factor that led for such systems to be developed is due to the system's reliability, which emphasise on the authorization in accessing the door, through a secure user interface [9] and [10].

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Smart Door System with IoT Application is one of the home automation element with internet-connected, servo-driven lock that can be operated remotely using a smartphone, through a free source mobile phone application, Blynk. Through Blynk, we can link our devices to the application and we can design our own interface for controlling and monitoring purposes.

2. Literature Review

Smart Door System with IoT Application comprises of two parts, which are hardware and mobile application. NodeMCU is chosen to be used in developing the prototype as it already consist both microcontroller and also a built in Wi-Fi module. As discussed in [8], same analogy is taken into developing this prototype to satisfy the IoT element as Blynk application will be used as the bridge between hardware and . It will be used to initiate the signal whether to lock or unlock the door. Same concept as [4] is taken into consideration by adding a live camera and motion sensor feature to ensure the safety of the front door. All of these features are accessible through Blynk.

2.1 Smart Door System

The evolution of smart door is getting secure and smarter. The algorithm of smart door nowadays are keyless and operated through another medium to replace the key. A basic smart door system commonly utilizing the usage of Wi-Fi or bluetooth technology that allow users to lock or unlock the door by sending secure signals from a various medium, such as through keypad system, mobile application, fingerprint, and face recognition. Table 1 below shows the various kind of keyless door system.

Table 1: List of smart door lock systems

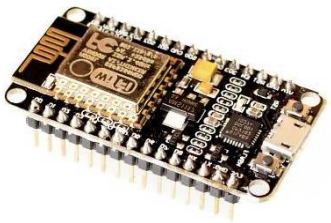
No.	Type of smart door system	Description	Picture
1	Wireless smart door lock	The medium used to lock and unlock the door is through mobile application [2, 4, 7, 8, 10]. The signal is send from a mobile application through Wi-Fi, and the lock will respond to the signal that is initiate by the mobile application. Figure 1 shows the example of the communication between door lock and mobile application on devices.	 **Figure 1: Wireless door lock**
2	Biometrics recognition door lock system	This system operate by using biometric technology, a system that use human's unique biology aspects to initiate signal [3]. Once the system recognize the owner's face and fingerprint, it will send the signal to the lock system. Figure 2 shows the example of the recognition process of human face and fingerprint to send a signal to door lock.	 **Figure 2: Biometrics recognition door lock**

3	Keypad-based door lock system	Keypad-based door lock system is used to allow user to lock and unlock the door by using a numerical password that is defined by the user [6]. It is supported by a deadbolt mechanism as the lock feature. Figure 3 shows the example of keypad door lock mechanism that is applied in the study.	 **Figure 3: Keypad-base door lock**

2.2 Microcontroller

In developing an IoT system, microcontroller plays an important role. Microcontroller is embedded into the system to control the function of devices and system by interpreting the data that is received from Input/Output (I/O) peripherals using the processor. The temporary information that received by the microcontroller is stored in the data memory. The processor will continue to accesses it and use the instructions stored in the program memory to decode and apply the incoming data. Once it is done, the I/O peripherals proceed to interact with the system and act accordingly. Shown in Table 2 below is the various type of microcontroller that is used in developing IoT system.

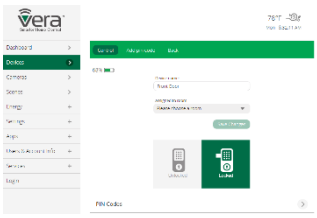
Table 2: Types of Microcontroller

No.	Type of Microcontroller	Description	Picture
1	NodeMCU ESP8266	NodeMCU is an open source IoT platform that is programmed in Arduino IDE [2, 8]. It has included a firmware that run on ESP8266 Wi-Fi SoC from Espressif Systems, and hardware that based on ESP-12 module. The programming to NodeMCU is similar to Arduino which make it is convenient to use. Figure 4 shows the example of NodeMCU ESP8266 used in the study.	 **Figure 4: NodeMCU ESP8266 Microcontroller**
2	Raspberry Pi (RPi)	RPi is a low cost computer that runs on Linux operating system [4, 9, 10]. It provides general-purpose input/output (GPIO) pins that enable us to control electronic components through physical computing. RPi is commonly used to run multiple programs. Figure 5 shows the example of RPi module that is commonly used for IoT system.	 **Figure 5: Raspberry Pi Microcontroller**

2.3 IoT Platform

In order to bring IoT based system alive, an IoT platform is needed in order to gather all the hardware, connectivity, software and application layers into one roof. IoT platform is functioned as a bridge between hardware and application layers. The main task of IoT platform is to collect data from the devices, remote device configuration and control, and also device management. Table 3 below shows the various type of IoT platform that is used in IoT system development.

Table 3: Types of IoT Platform

No.	Type of IoT Platform	Description	Picture
1	Zigbee Technology	Zigbee technology is used as a platform for IoT system, as the architecture of the technology is built specially for home automation system [1]. Zigbee module is used to connect the sensors network that is embedded to the door lock system. Figure 6 shows the example of Zigbee module that is used in Zigbee technology.	 **Figure 6 : Zigbee Module**
2	Blynk Application	Blynk is a IoT platform that is compatible for both IOS and Android devices that is used to control various kind of microcontrollers [8, 10]. Blynk allow us to build our own interface by adding the widgets that is provided by Blynk. Figure 7 shows the example of Blynk interface that has been customized for IoT system.	 **Figure 7 : Example of Blynk interface**
3	Web Application	Creating a specific website for controlling IoT devices is also another platform for IoT system. The website is programmed to be able to provide functions such as user registration [3], monitor door state and send email to owner [7], and also a door permission system between owner and visitor [10]. Figure 8 shows the example of web interface acting as an IoT platform controlling the IoT system.	 **Figure 8 : Example of web application interface**

Based on the studies [1 – 10], the most suitable analogy is taken into developing the prototype of Smart Door System with IoT Application. The goal of this project is to create a keyless door system. Thus, wireless door lock system is the best algorithm to be used. In order to achieve wireless system,

NodeMCU ESP8266 is chosen as the microcontroller as it has built-in Wi-Fi module, which can minimize the design of this prototype. In order to develop a user-friendly system, Blynk application is used as the IoT platform to control the IoT system of this prototype. This is because, Blynk application is available on both IOS and Android platform, which make it is easier to be downloaded by users.

3. Methodology

The design of the prototype is made with the fulfillment of the project objectives. The prototype is made by using low cost components such as PIR Motion Sensor, MG995 Metal Gear Servo, and ESP32 Camera. All of these component are connected to NodeMCU ESP8266, which is the microcontroller that has an integrated Wi-Fi module that can connect to Blynk server that works as the IoT platform for this prototype. The operation is controlled and monitored through Blynk application, that is accessible on all mobile devices. The flow of the process is as shown in the flowchart in Figure 9 below.

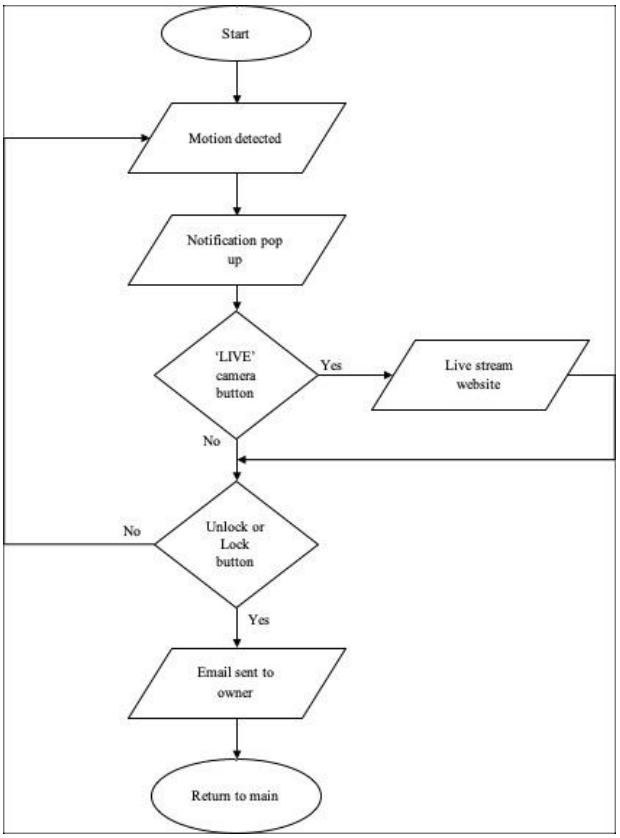


Figure 9: The process flowchart of the prototype

3.1 Block Diagram

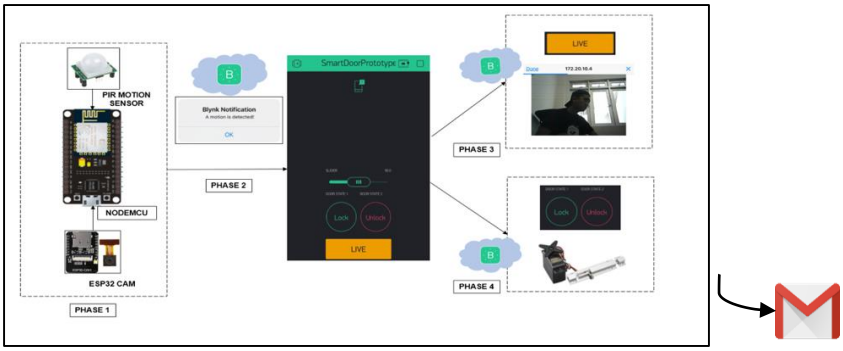


Figure 10:The block diagram of the prototype operation

Shown in Figure 10 above is the block diagram of the prototype of Smart Door System with IoT Application works. It shows the flow from the input to the output of the system. The block diagram is separated into four phases, which indicate the flow of the operation of the prototype.

The first phase indicate the initial process of the prototype, which are motion sensor and camera module. Motion sensor will detect motion within its range and send data to NodeMCU. Meanwhile, camera module will act as a live camera to capture the live environment at the front door. Between every phases, there are Blynk Cloud, which will act as a bridge of communication between hardware and our mobile device.

Phase 2 indicate whenever a motion within the range is triggered at Phase 1, a notification will pop up and we can click to the notification to open our Blynk interface. The Blynk interface has been customized with a notification bar, lock and unlock button, and also a 'LIVE' button that will direct us to live camera streaming.

Phase 3 indicate our action towards the state we received at Phase 2. In Phase 3, we can use the live streaming function to identify the person in front of our door. The servo motor is adhered to the door latch, purposely to change the state of the door, whether to lock or to unlock the door. In Phase 4, the lock and unlock button in Blynk will communicate with NodeMCU in Phase 1 and simultaneously change the state of the door latch. For every changes detected in the door latch, an email will be sent to owner regarding the door current state.

3.2 List of Materials

The IoT element of this prototype is delivered through the controlling device for the door system by using a mobile application. A microcontroller is programmed to communicate with the application's cloud system and initiate signals of sensor, servo motor and camera module that is connected to the microcontroller. Listed in Table 4 below is the list of the materials that are used in developing this prototype.

Table 4: List of materials required in developing the prototype

No.	Component	Function	Specification
1	NodeMCU ESP8266	Act as the backbone of the system. With built in ESP8266 Wi-Fi module, it can be connected to the Internet without using additional component. It act as the mediating way of communication between software and hardware devices.	An open-source fimware and development kit that is perfect to build IoT prototype. It includes firmware which runs on ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module.
2	MG995 Servo Motor	It is used as the actuator of the door latch. This servo provide a precise rotation of 180º and a metal gear, which make it strong to move the door latch with a specified angle.	A 55g digital metal gear high torque servo that have a high speed rotation for quick response. It has an excellent holding power and also a stable design. The maximum load of current is 1200mA.
3	PIR Motion Sensor	Used to sense a movement of people in the range of 10m from the sensor.	Made of pyro-electric sensor, which can detect various levels of infrared radiation. It act as a

			digital output that depends on high or low flip. Once the sensor warms up, the output will remain low until a motion is detected, it will turn to high.
4	ESP32 Camera Module	Serves as the wireless video monitoring.	Small camera module embedded to ESP32-S chip. It has built in Wi-Fi and Bluetooth, with an additional 4MB of external RAM.
5	Blynk Application	Act as a IoT platform for controlling and monitoring this prototype. User interface is created and customized in this application. It can be used to receive input from the devices and also trigger an output to a device.	A digital dashboard where we can build a graphic interface by using provided widgets and customize it to give our desired outputs. It is available on both IOS and Android platform, which makes it user friendly.

3.3 Software Development

In the process of developing this prototype, NodeMCU ESP8266 is programmed by using Arduino IDE. The program is structured to connect a defined Wi-Fi connection and connect it directly to Blynk server through a default gateway. The motion sensor is programmed to send a notification to the Blynk application, and we can use other feature that have been programmed through Blynk application, such as live camera streaming and automatic lock feature.

Upon setting up Blynk, an authentication code will be generated in order to pair it with our coding in Arduino IDE. Blynk will recognize the program through the authentication code and connect it to the Blynk gateway. Figure 11 below shows the program example how to define the authentication code, SSID and password. Meanwhile in Figure 12, shown the example of interface customization process in Blynk application.

```
char auth[] = "54412db453db4628a15b12e9cf95af77"; // Blynk authentication code
char ssid[] = "Ummi Nisa"; // Wi-Fi SSID
char pass[] = "NISA1234"; // Wi-Fi password
```

Figure 11: Coding in Arduino IDE to define authentication code, SSID and password

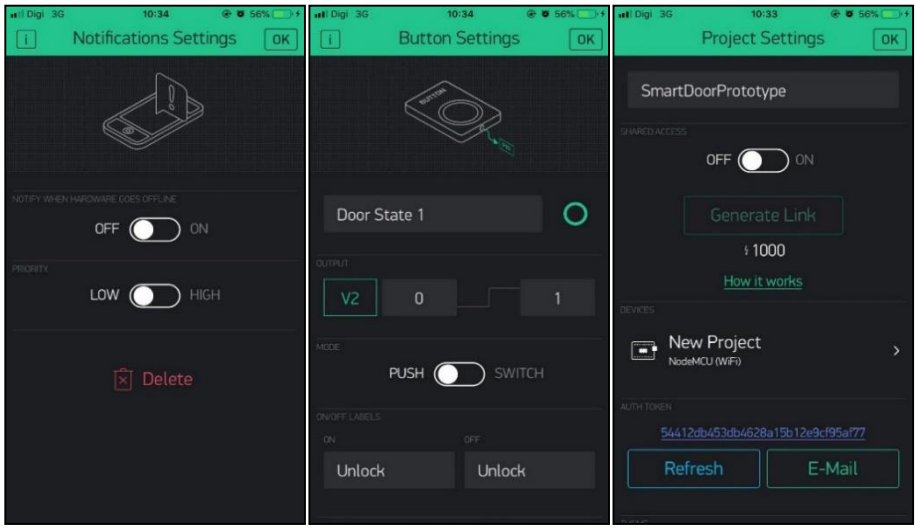


Figure 12 : Setting up Blynk application and function customization (a) Setting up main project and board selection; (b) Customizing the button settings;(c) Customizing the notification settings

On the other hand, ESP32 Cam is a stand-alone device, and the program for the camera is done separately from the whole prototype. The camera is programmed to connect to the same Wi-Fi connection as the NodeMCU, which enable it to be accessed under the same user interface with NodeMCU. Once the code is uploaded to the ESP32 Cam, an IP address will be given that we can use for live video streaming. The same IP is used to connect it to Blynk application, to enable it to be accessed under Blynk interface. Figure 13 below shows the example of customizing the link for live camera stream in Blynk application.

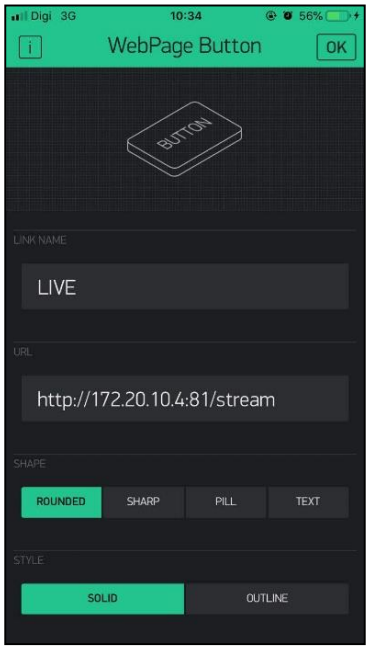


Figure 13: Blynk interface customization for ESP32 Cam

4. Result and Discussion

The prototype has been tested and it has achieve the objectives of this project. The Blynk interface was successful to control all the devices that are connected to the NodeMCU. ESP32 Cam is also

successfully connected to the NodeMCU and streamed under the same interface with NodeMCU in Blynk application. Figure 14 below shows the final hardware design of the prototype.

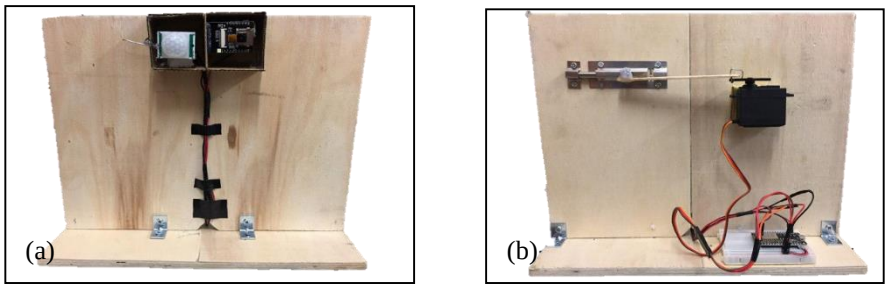
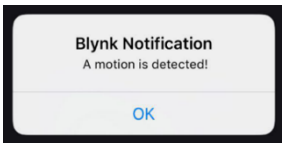
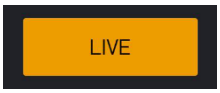
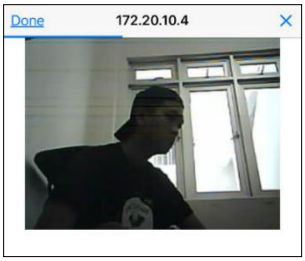


Figure 14: Hardware design (a) Front side of hardware design; (b) Back side of hardware design

The interactive communication between Blynk application and NodeMCU has given the expected output of this prototype. The output for each functions of the prototype is as shown in Table 5 below.

Table 5: Output for each functions of prototype

No.	Input	Output
1	 **Figure 15 : Notification widget customized on Blynk**	 **Figure 16 : Notification when a motion is detected**
2	 **Figure 17 : Button to access live camera stream**	 **Figure 18 : Live camera stream webpage**

3

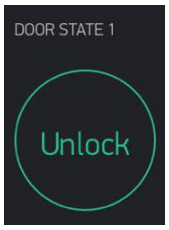
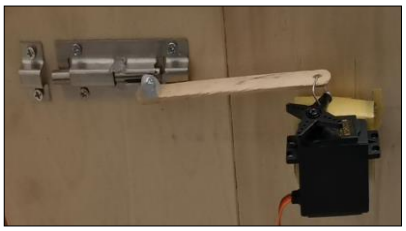
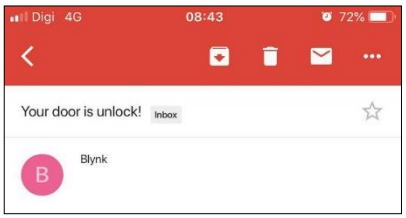


Figure 19:Unlock virtual button



(a)



(b)

Figure 20: Output when 'Unlock' button is pressed (a) The door latch is in unlock state; (b) An email received regarding the state of door latch

4

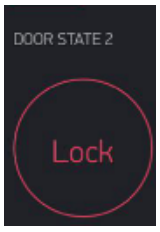
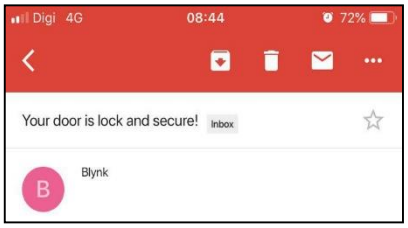


Figure 21: Lock virtual button

(a)



(b)

Figure 22: Output when 'Lock' button is pressed (a) The door latch is in lock state; (b) An email received regarding the state of door latch

Based on Table 5, the components that is used in this prototype development has proven it's capability to deliver the expected outputs. Apart from that, numbers of testing is done to the prototype and the result is recorded as in Table 6 below.

Table 6:Testing result

No.	Testing Function	Result of the testing		
		Number of testing	Success	% of success
1	Blynk notification of motion sensor	30	28	93%
2	Lock virtual button	30	30	100%
3	Unlock virtual button	30	30	100%
4	Live camera streaming	30	28	93%
5	Email on lock state	30	30	100%
6	Email on unlock state	30	27	90%

Based on Table 6, some of the functions are unable to reach 100 % of success due to few limitations. Blynk notification of motion sensor is detected to be really sensitive to the surroundings, which bound to give a false notification to the user. Meanwhile, live camera streaming is bound to fail due to slow Internet connection. On the other hand, the email is functioned with time interval of 5 – 10 seconds. Too fast decision on the lock system caused the email failed to be generated [7]. Overall, this prototype achieved 96.0 % of success.

5. Conclusion

In a nutshell, the development of prototype Smart Door System with IoT Application is a simplified example of smart door system algorithm. In developing a prototype, it is better to minimize the design and reduce the power consumption. NodeMCU works best in this prototype development as it provide enough pins for the components and also easy to program. Using other microcontroller such as RPi might be slightly overkill as it is programmed in Linux operation system, which makes the process complicated. This prototype has proven that same outputs could be achieved by using NodeMCU. The IoT platform plays an important role in this prototype development. In this era, the usage of mobile devices is applied to almost everything we did in our daily basis. Thus, choosing Blynk as the IoT platform is the best decision since it can be accessed through our mobile devices. The customization of interface is also a lot easier than implementing a web interface in order to develop a monitoring system. Smart Door System with IoT Application can be compared with the conventional door system in terms of its performance. Technically, by make use of the technology such as Wi-Fi and IoT platform, it has increase the responsive rate of the system as Wi-Fi connection operates at 2.4GHz and the responsive time is less than 1 second, approximately 0.4 – 0.5 seconds per interaction.

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