

Improving Smart Home Concept with the Internet of Things Concept Using RaspberryPi and NodeMCU

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Abstract. The Internet of things (IoT) is getting more tractions in recent years. One of the usage scenario of IoT is smart home. Smart home basically provides home automation for installed devices at home such as thermostat, lighting, air conditioning, etc and allows devices connected to the Internet to be monitored and controlled remotely by user. However many studies on smart home concept focusing only on few main features. They still lack of important usage of IoT i.e. providing energy efficiency, energy monitoring, dealing with security, and managing privacy. This paper proposes a smart home system with RaspberryPi and NodeMCU as the backend that not only serves as home automation and merely a switch replacement, but to also record and report important things to the owner of the house e.g. when someone trespasses the house (security perimeter), or to report the calculation of how much money has been spent in consuming the electrical appliances. We successfully examine our proposed system in a real life working scenario. The communication between user and the system is done using Telegram Bot.

Keywords: Smart Home, IoT, Home security, Home automation

1. Introduction

Housing is one of the primary needs of society. With better economic situation, the demands of having a safe and comfortable home is increasing. Technology is one of the things that able to affect the security and can create comfort of a home. Smart home aims to make homeowners feel more comfortable and safe when he is inside or outside the house. Smart homes once hailed as the domain to the rich but now slowly and steadily becoming a necessity for many people in urban areas due to its ubiquitousness as the price are getting cheaper year by year. The IoT helps smart home adoption in many places, and among the features that attracts many people are security and automatic control features [1].

Smart home is not a new concept. The first smart home technology named X10 was developed by a company in Scotland in 1975 [2]. A smart home appears "*intelligent*" because its computer systems can monitor many aspects of daily living. As the number of controllable appliances in the home rises, the ability of these devices to interconnect and communicate with each other digitally becomes useful and desirable feature [3]. The term Internet of Things (IoT) was first introduced by Kevin Ashton in 1999 [4] where it allows a device that is naturally not connected to the network to be connected to the internet and can be monitored and controlled remotely by user. Most research on smart home is now only focus on one or two main features only, and rarely discusses on the integration of multiple features such as how to achieve energy efficiency, intensive monitoring, security enhancement, and maintaining privacy. To fill the gaps in the IoT research, we design and build a smart home prototype with internet of things concept using RaspberryPi and NodeMCU that integrates enhancement features. We proposed a smart



home that is not only serve as a substitute for mechanical switches to turn on or off electrical devices but also record and report important things related to the home owner, such as home security. Our proposed work can make a report if there are people who trespass into the house. The proposed system can also calculate the power that has been used by electronic devices so that homeowners can save money in electricity bills. This greatly helps the homeowner to monitor the house even when he is not at home.

2. Literature Review

Since smart home technology was first introduced in 1975, many researchers have discussed the topic very well. Starting 2010, the smart home topics most widely associated with IoT [5]. Panna et. Al [6] in their research developed the *Development of Energy Saving Smart Home Prototype*. This research discusses the making of a smart home prototype using PIC18F458 microcontroller. The main purpose of this prototype is to save electricity. The prototype only uses temperature and infrared sensors. The temperature sensor is used to regulate the air conditioning and infrared sensors to detect human presence in the room. microcontroller will decide whether the air conditioner and the lights should be on or off based on the sensor readings. The estimated the cost of electricity usage will be recorded into a database that can be accessed by the user.

In other research, Piyare and Song [7] proposed a *Smart Home-Control and Monitoring System Using Smart Phone*. This research discusses the smart home control and monitoring using micro-web server and smartphones. Micro web-server installed on arduino used to transmit data from the sensor to smartphone user, then the user can send commands to arduino to control electronic devices. There are other research discusses the use of microcontroller in smart home environment such as Raspberry Pi Interactive Based Home Automation System through the Internet of Things [8]. This research discusses the home automation system using the Raspberry Pi and MSP430 microcontroller. Raspberry Pi acts as a master and MSP430 as a slave. MSP430 sensor will transmit readings to the Raspberry Pi, and raspberry will decide what commands will be sent to the slave or the other slave.

Other research discusses on how a smart home was built with GSM based automation [9]. This research discusses the home automation system using arduino microcontroller connected to the GSM modem controlled from android smartphone. This automation system is only used to turn on or turn off electronic devices. On another study, smart home was built using email as the platform [10]. This research discusses home security system using facial pattern recognition to get into the house. This system uses a BeagleBone and cameras. The System used email to make communication with users. Another study proposed a prototype of smart home intelligent lighting control architecture onboard sensors using a mobile computing system [11]. This research discusses a prototype of a smart home by using Ambient Light Sensor on smartphones. The readings from these sensors will be sent to the Arduino Uno and forwarded to the Raspberry Pi to decide whether the lights should be on, dim, or off.

From some previous research it can be seen that most smart home systems were made with only one or two functions just like a remote control for an electronic device or an electronic device automation. Therefore, we decided to make a smart home prototype using the Raspberry Pi and NodeMCU. The main features of our prototype made are automation, control, monitoring, and security. The automation will create an automation e.g. lights that is based on human presence. The control feature is able to turn on and off electronic devices remotely. The monitoring feature to determine the approximate cost of electricity from every electronic device. Security to keep the house from thieves when the owner was not at home.

3. Proposed System

The system is developed using the Raspberry Pi and NodeMCU as the main components. The communication between Raspberry with NodeMCU are using MQTT, while the communication between users and Raspberry using a Telegram bot. Other components used in the development of this prototype are sensors that consists of rain sensor, door sensor, passive infrared sensor (PIR), and DHT22

(temperature and humidity) sensor. The proposed block diagram of smart home prototype as presented in Figure 1.

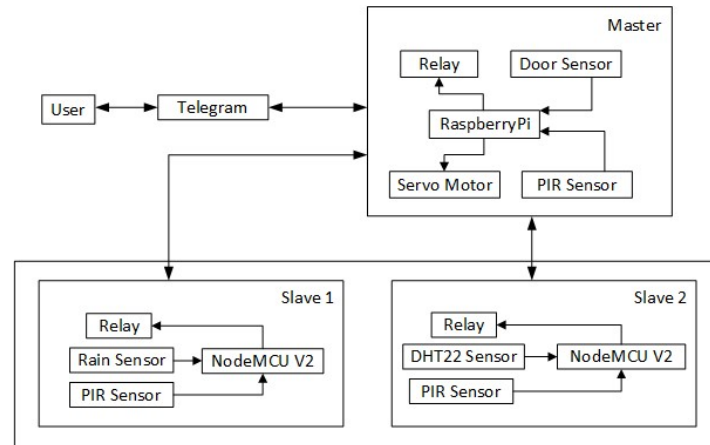


Figure 1. Block diagram of smart home prototype

The system has 3 modes which can be selected by the user; the modes are auto, manual, and secure. Auto mode works by detecting the presence of a human using a PIR sensor and a temperature sensor using DHT22. If the PIR sensor detects human presence in the room, the sensor will transmit the readings to the Raspberry Pi results, then the Raspberry Pi will instruct the relay to turn on the lights that are in the room. DHT22 sensor is used to determine whether the air conditioning should also be turned on or not.

Manual mode works by waiting for user commands given to the system via bot telegram. The secure mode is used when the user is not at home. When secure mode is active, PIR sensor and door sensors will work continuously. The system will send a warning message to the user if any suspicious activity is detected by a sensor such as detecting the presence of human or door is open when no one at home. The locations of sensors and relays on our smart home prototype is presented in Figure 2.

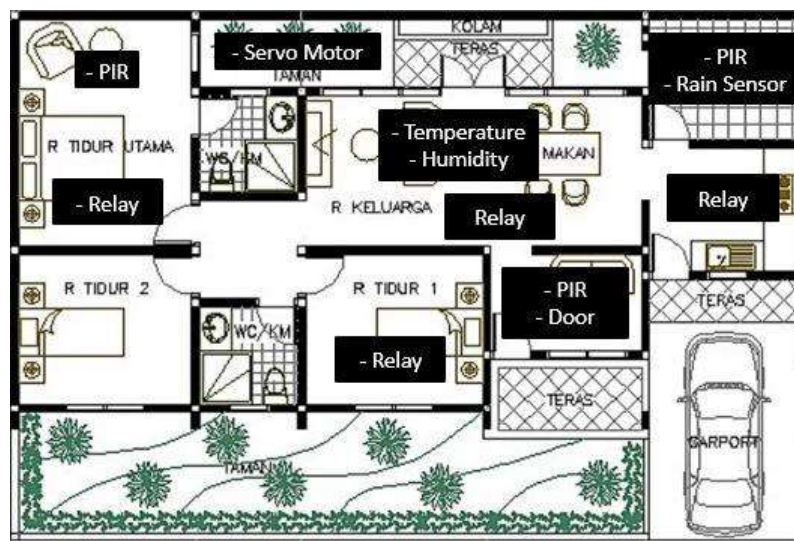


Figure 2. location of sensor and relay on smart home prototype

Because the result of this research is a prototype, it is necessary to do some manipulation for testing purposes. The objective is to get the conditions according to actual events. Conditions and sensor manipulation are presented in Table 1.

Table 1. Condition and Sensor Manipulation

Condition	Sensor manipulation
<i>There are human</i>	Open the PIR sensor cover and Moving the hand in front of the sensor.
<i>There is no human</i>	Installing the PIR sensor cover.
<i>Rainy day</i>	Drops of water on the rain sensor.
<i>Sunny day</i>	Drying the rain sensor.
<i>Turning on and off electronic devices manually</i>	Send a message to telegram bot to turn on or turn off electronic devices.
<i>Temperatures above 30°C</i>	turn on the smartphone's flash light near the sensor.
<i>Detecting thief</i>	Turn on secure mode and moving the hand in front of PIR sensor.

4. Implementation

We build our prototype with Raspberry Pi as a master and MQTT broker, NodeMCU as a slave, and MQTT as a communication protocol between Raspberry and NodeMCU.

4.1. RaspberryPi 3 Model B

Raspberry Pi is a credit card sized computer. It is a capable little computer which can be used in electronics projects, and for many of the things that desktop PC does [12]. Raspberry Pi used in this research is the Raspberry Pi 3 Model B. It is selected because the price is cheap and the amount of community supports. Figure 3 shows Raspberry Pi 3 Model B and its pin diagram.

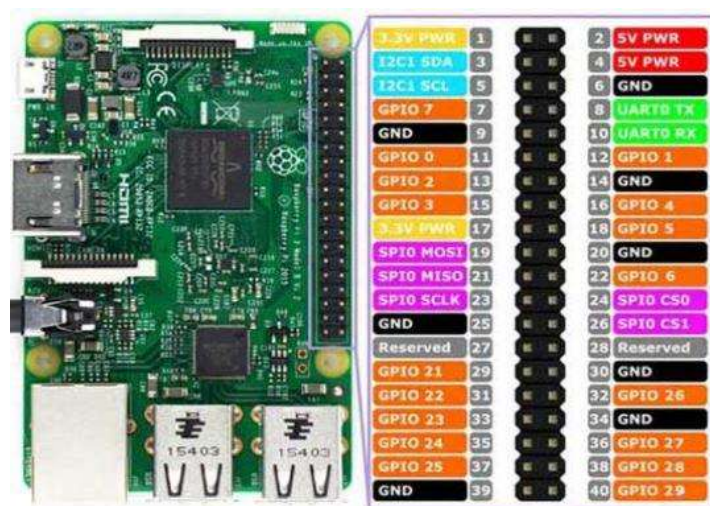


Figure 3. Raspberry Pi 3 Model B

The operating system used on this raspberry is Raspbian OS. After the operating system is installed we then proceed with the installation MQTT so that Raspberry Pi can become MQTT broker. Devices that are installed in Raspberry Pi consists of sensors, relay, and servo motors. Pin Configuration for each device on Raspberry Pi can be seen in Table 2.

Table 2. Pin Configuration for each device on Raspberry Pi

Device	Pin	Raspberry Pin
PIR sensor	VCC	01 (3.3V)
	GND	14 (GND)
	OUT	04 (GPIO04)
Magnetic Door Sensor	GND	09 (GND)
	OUT	03 (GPIO02)
Relay	VCC	04 (5V)
	GND	06 (GND)
	IN1	18 (GPIO24)
	IN2	16 (GPIO23)
	IN3	12 (GPIO18)
	IN4	10 (GPIO15)
	IN5	08 (GPIO14)
	IN6	-
	IN7	-
	IN8	-
Servo Motor	VCC	02 (5V)
	GND	34 (GND)
	SIGNAL	40 (GPIO21)

After the Raspberry Pi configuration is complete, we then proceed with NodeMCU configuration that serves as slave to transmit sensor readings and receive commands from RaspberryPi.

4.2. NodeMCU V2 ESP8266

NodeMCU first was developed in 2013 by a Chinese company named Espressif makes a System on Chip (SoC) called ESP8266. NodeMCU is IoT platform that is open source and uses the Lua programming language. In its development, NodeMCU can finally be programmed using Arduino IDE so it can run the libraries used by arduino. NodeMCU is selected because of its cheap price and the extent of community support. NodeMCU V2 and its pin diagram can be seen in Figure 4.

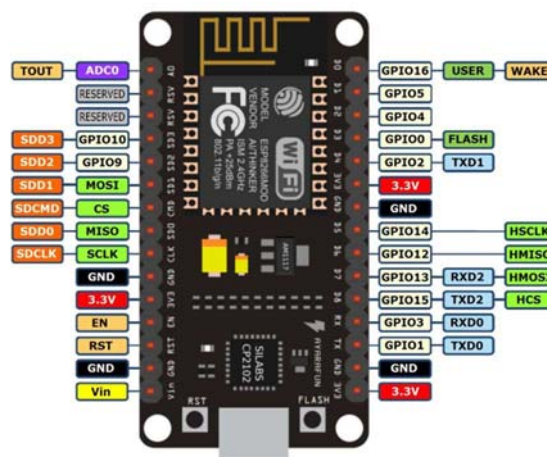


Figure 4. NodeMCU V2 ESP8266

This research uses 2 NodeMCU. First NodeMCU device installed with DHT22 sensors, PIR, and relays. The second one installed with rain sensors, PIR, and relays. NodeMCU pin configurations for each device are presented in Table 3 and Table 4.

Table 3. Pin Configuration for each device on NodeMCU 1

Device	Pin	Pin NodeMCU
PIR sensor	VCC	VCC
	GND	GND
	OUT	D6
DHT22 sensor	VCC	VCC
	GND	GND
	OUT	D7
Relay	SIGNAL	D5
	GND	GND

Table 4. Pin Configuration for each device on NodeMCU 2

Device	Pin	Pin NodeMCU
PIR sensor	VCC	VCC
	GND	GND
	OUT	D8
Rain sensor	VCC	VCC
	GND	GND
	AO	A0
	DO	-
Relay	VCC	VCC
	GND	GND
	IN1	-
	IN2	D2
	IN3	D3
	IN4	D4
	IN5	D5
	IN6	D6
	IN7	-
	IN8	-

After NodeMCU configuration is complete. Then proceed with installing MQTT in Raspberry Pi so it can communicate wirelessly with NodeMCU.

4.3. Message Queue Telemetry Transport (MQTT)

Message Queue Telemetry Transport (MQTT) is a Machine-to-Machine (M2M) / "Internet of Things" connectivity protocol. MQTT is selected because it is a lightweight messaging protocol. MQTT send and receive messages in a very small size. MQTT use publish and subscribe concept to send and receive message, it is client and server based. Server which is better known as the broker receives a message from a client, it can be data message publish or subscribe. MQTT is not a new protocol, created by Dr. Andy Stanford-Clark from IBM and Arlen Nipper from Arcom (now Eurotech) in 1999[13]. MQTT publish-subscribe architecture can be seen in Figure 5.

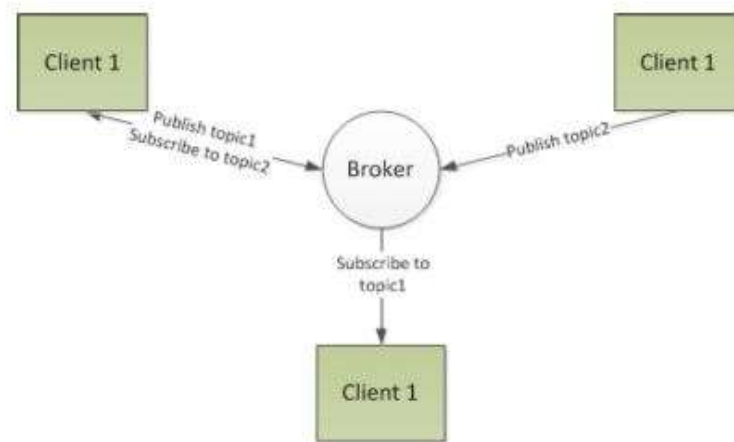


Figure 5. MQTT publish and subscribe architecture

TO increase the reliability, MQTT offered three types of modes which are called Quality of Service (QoS) [14], Detailed information about each QoS MQTT can be seen in Table 5.

Table 5. Various QoS on MQTT

QoS	Information
0	Messages are sent once and does not require confirmation or Acknowledge (ACK).
1	Ensuring that messages are sent at least one time and requires ACK.
2	Ensuring that messages sent exactly once.

Once the configuration is complete and Raspberry can communicate with NodeMCU via MQTT. The next step is to install the entire prototype model. Figure 6 shows our final prototype that already assembled.



Figure 6. Prototype Smart Home

5. System Testing and Analysis

After the configuration and the assembly of each device on a prototype smart home is completed, we tested with multiple scenarios based on actual events. The conditions and the test results can be seen in Table 6.

Table 6. The conditions and results of testing

Condition	Supposedly output	Test result
User are outside. User select auto mode. User enters the living room. The temperature in the living room 26°C.	Living room lights automatically on.	valid
User are in the bedroom. User selects auto mode. There is a clothesline in the backyard. Users walk into the living room and backyard Rainy day.	Lamp in living room and backyard automatically on. Roof closed.	valid
User are in the living room. User selects auto mode. The weather was hot and the room temperature of 30°C.	Lights and AC automatically on.	valid
User are in the living room. User change auto mode to manual mode. Due to an error input, the user must change the power and lifespan e6 (lights) on the database to 12 Watt power with lifespan 15,000 hours, from the previous 8 Watt power with lifespan 13,000 hour. User turn off and then turn on the lights.	Light off then back on, and the calculation of power and lifespan of the lamp is using the latest input.	valid
User are in the bedroom. User manually turn on the lights.	The light was on and then off. Once the lights are off, the user will receive a message from the system that said the lights are off with the remaining lifespan of the lamp.	valid
Users get out and turn off the lights manually.		
User are in the bedroom. User selects secure mode. User running toward the backyard.	Users detected as a thief.	valid

We then analyse the usability of our system and classify both advantages and disadvantages of the system as presented by Table 7.

Table 7. Advantages and disadvantages of the system

Advantages	Disadvantages
<ul style="list-style-type: none"> • Replaces the manual switch at home. • Noting the estimated cost of electricity for every electronic device. • Improve home security. • The system does not require a great power. • Users can control and monitoring the house remotely. 	<ul style="list-style-type: none"> • Command to the system by sending a message, that is not practical for the user. • Telegram bot for the system can be used by many users, but should be included in the same group chat so that everyone can send commands to the system.

6. Conclusion

Based on our testing and analysis, it can be concluded that our prototype works well. The main function of this system is automation, control, monitoring, and security. Automation and remote control enables users to operate the electronic device even when users are not at home. Monitoring function can help users to estimate the cost of electricity usage for any electronic device. Security functions may provide a sense of security to users when they're not at home because the system will work continuously and report any suspicious activity that detected by the sensor. It is expected that this prototype can be the basis for further smart home development with better security and more functions.

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