Home Automation Application Using Raspberry Pi 3 and Windows 10 IoT

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Abstract*:* In the present situation demand for electricity stack, up with population growth is one of the major challenges all over the world. Inadequate amounts of electricity create an awareness to conserve energy in all viable methods. As a result, we made an appliance to minimize the energy wastage by the concern of Smart Home. Home automation refers to controlling home appliances and domestic features by local networking or remote control. The devices' respective apps in smart homes allow users to track energy usage over time. They can also get an estimate of how much they are paying for whatever they have plugged in. By and by this will have an impact on consumer behaviour and will help people to be more energy conscious and, in the long run, responsible. Apart from that, the current commercial home automation systems are general and have not to consist specific designed for the Sri Lankan contest. So, we designed a smart home automation system with the sense of Sri Lankan electricity tariffs and practices. This scheme involves the design and construction of individual control home appliances using Raspberry Pi 3, Arduino, and Windows 10 IoT core. This combination can implement the primary home automation functions by using numerous sensors, with that it will deliver suggestions and illustrate the process of the electricity tariff system to the users. With this attempt, the consumer can reach optimum power consumption.

Keywords: *Raspberry Pi, Arduino, Smart Home Automation, Power Measurement, IoT*

1. Introduction

The Ceylon Electricity Board is the largest electricity company in Sri Lanka. With a market share of nearly 100%, it controls all major functions of electricity generation, transmission, distribution, and retailing in Sri Lanka. It is one of the only two on-grid electricity companies in the country; the other being Lanka Electricity Company. One of the major problems in Ceylon Electricity Board (CEB) is producing higher demand electricity with allocated funds. The financial crisis of CEB is not only a problem for the CEB but also a problem for the development of the country. For example, due to the financial crisis, CEB is keeping a non-payment of Rs.35 billion (On the date of Sep 29, 2017) to Ceylon Petroleum Corporation. Lack of knowledge among consumers about their electricity tariff system is the major reason for the problem. The end solution is a simple single device that can act as smart home automation as well as assist and give suggestions to the users to optimize their power consumption to reduce their electricity tariff. On the other hand, it supports a lot to the

CEB to overcome their financial crisis, so better for the development of the country.

Generally, the benefits of the Smart home project are by no means limited to convenience, although this is a compelling feature. Smart homes also have the potential to be greener and cheaper. This program is to optimize energy consumption and reduce our electricity bills. And, this technology offers the prospect of significant improvements in living standards.

Application of the Home automation system is moving at the rate of high, they are used to grand comfort, convenience, high quality of life, and smart security for householders. At present days, many home automation systems are used to provide support to elderly and disabled people and they eliminate the manpower in the production of services and goods [1-2]. The Home automation system can be designed and created by using a single controller which has the strength to curb and monitor different interconnected appliances such as power plugs, lights, temperature and humidity sensors, smoke, gas, and fire detectors as well as emergency and security systems [3].

The best superiority of a home automation system is it can be controlled and managed easily from an array of devices such as smartphones, tablets, desktops, and laptops [4]. The rapid growth of wireless technologies influences us to use smartphones to remotely control and monitor home appliances around the world [5-6]. Many home automation systems use them automatically connect with a wireless handset communication technology, such as Bluetooth [7], GSM [8], ZigBee [9], Wi-Fi [10], and EnOcean [11]. Smartphone sequential network communication application errand users can modify their system settings and personal equipment. Different types of home automation systems provide a wide range of services and services, some typical functions include instrument control, temperature control, Remote lighting, video surveillance, monitoring of a re-view camera, and a real-time text warning.

All the power consumers can be potential customers due to the home automation and remote controlling feature. But to fully utilize the whole system with the power assistance and suggestion feature, the power consumers who fall under the domestic user section and who consume more than 60 units per month in Sri Lanka.

Home automation is very common nowadays, but it can only perform home automation and remote control. There is no knowledge-building or awareness-raising process for the home automation, so we have developed a system called Smart Home Application which can perform the basic operations of home automation as well as creates awareness of Sri Lanka's electricity system and how can we utilize the electricity system effectively. The project Smart Home Automation Application helps the end-users to identify their power consumption pattern and from that, they can optimize their power usage.

Features of the Smart Home Electricity Assistant are as follows.

- Electrical appliances can be controlled via a dedicated display panel.
- Electrical appliances can be controlled remotely using smartphones and tablets.
- The power consumption of each appliance can be monitored.
- The status of a room such as Temperature, Light intensity, and Presence of humans can be observed.
- The home lighting system can be controlled automatically with room light intensity and the presence of humans.

- Automatic switching between fan and air-conditioner concerning room temperature.
- Sri Lanka's electricity tariff system and ideal power-saving tips in the contest of Sri Lanka can be observed in the information tab, from which the consumer can perform some demand-side management and he can reduce his tariff.

The rest of the paper explained related work, the proposed method, and results and discussion.

2. Related Work

A. Evolution of home automation application

The idea of home automation is not a recent concept anyhow it has been more of a case of technology catching up with the idea. It all started with the wireless remote control, which was first unveiled by Nikola Tesla in 1898 when he controlled a miniature boat by sending it radio waves. The 20th century started with the boom in home appliances such as the engine-powered vacuum cleaner in 1901 and the electric-powered vacuum 6 years later.

The idea of home automation was flirted with in the 1930s but it wasn't until 1966 Jim Sutherland developed the first home automation system "Echo IV" which would make a shopping list, control temperature, turn appliances on and off but this was never commercially sold. 1969 saw the Honeywell Kitchen Computer which was a commuter that would create recipes, although this had no commercial success due to the price. The microprocessor came in 1971 and this meant a rapid price fall in electronics, which meant technologies become more accessible to everyone. The term Smart Home was first coined by the American Association of house builders in 1984. Through the 1990's there was a new focus on combining gerontology which technology to help improve the lives of the elderly and less able. Gradually as technology became more affordable, these technologies slowly become integrated into our homes. Along this, we take the smart home a step forward with the Internet of Things (IoT) and assistive.

B. Existing Work

The application has been developed based on the android system [2]. An interface card has been developed to assure communication between the remote user, server, raspberry pi card, and the home Appliances. The application has been installed on an Android Smartphone, a web server, and a raspberry pi card to control the shutter of windows. Android application on a smartphone issue command to raspberry pi card. An interface card has been realized to update signals between the actuator sensors and the raspberry pi card. A smart home based on Raspberry Pi, Arduino, and Windows IoT has been proposed [3]. The Project offers a Windows application for operating several devices from a single device remotely where users can control lights, fans, the temperature of heaters, the speed of the fan, and switches from one place. In the case of lights, the system will turn on the lights if the motion sensor is active and natural light is below the required density. Similarly, fan speed is automatically controlled based on room temperature. Shih-Pang Tseng et al. [4] proposed Smart House Monitor & Manager (SHMM), based on the ZigBee, all sensors and actuators are connected by a ZigBee wireless network. They designed a simple smart socket, which can be remote controlled via ZigBee. PC host is used as a data collector and motion sensing, all sensing data are transferred to the VM in the cloud. The user can use the PC or Android phone to monitor or control through the Internet to power-saving the house.

Arduino microcontroller to receive user commands to execute through an Ethernet shield. This house organize framework utilized together both wireless ZigBee and wired X10 advancements [5]. This system followed smart task scheduling with a heuristic for the

Resource-constrained- scheduling problem (RCPSP). The mobile device can be either wired to the central controller through a USB cable or communicated with it wirelessly, within the scope of the home. Arduino contains the web server application that communicates through the HTTP protocol with a Web-based Android application. The system is highly flexible and scalable and expandable. PIC16F887 microcontroller for home appliances controls with GSM for control of the appliances [6]. It has high availability, coverage, and security but the cost of SMS. AT commands can be sent through the GSM network to control the home devices. The system does not have any state information related to the devices and expects the user to keep track of it.

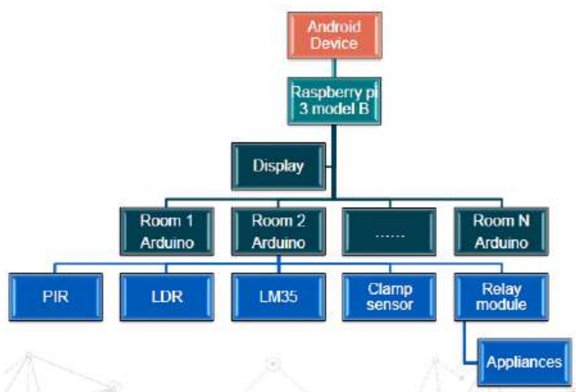


Figure 1. Block diagram of Home

3. Proposed Method

As shown in Figure 1, Raspberry Pi 3 Model B was used as the main master device. The Raspberry Pi 3 is running on Windows 10 IoT core. The Raspberry Pi 3 controls and monitors all slave devices that are Arduino UNOs through the I2C bus protocol. Raspberry Pi 3 has Wi-Fi and Bluetooth connectivity compare with other microprocessors. Also, it has a very big performance boost and 1.2 GHz quad core processor.

Each Arduino UNO controls one room. Arduino UNO collects all the sensor data and its device's statuses, then it just sends the data to the master device which controls everything. In the case of wireless device connectivity, an Arduino Pro Mini is used to manage the wireless devices. NRF24L01+ module is used to create the 2.4 GHz wireless channel. Users can interface with the system via the dedicated display at the master device or from their smart mobile devices which have Wi-Fi connectivity. The wireless unit was designed such that users can just plug in and use it. The automation process of lights and fans was assigned to the slave device Arduino UNO to reduce the load on the master device Raspberry Pi. The controlling software and the GUI platforms were designed using C#.

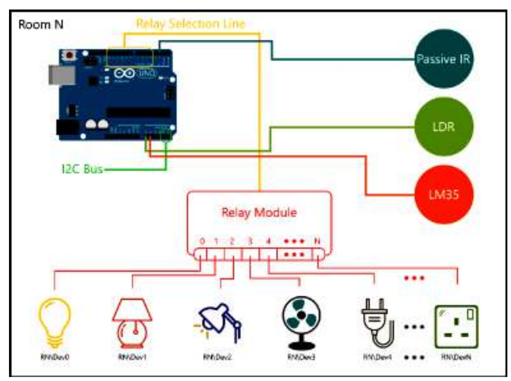


Figure 2. Block diagram of Room

Extensible Application Markup Language (XAML) was used to create the GUI for the application and the application was developed using C# because the Windows 10 IoT core is the best suited with C#. Microsoft Visual Studio 2017 was used as Integrated Development Environment (IDE) for the application. This IDE was selected because the targeted OS platform and the IDE both were from the same developer Microsoft, so it has greater debugging options and compatibilities.

Figure 2 elaborate how sensors and relay module are connected with Arduino. One relay module can connect several devices. The main reasons for selecting particular types of components are given in Table 1.

Table 1. Used components and properties

Type of component	Properties
Raspberry Pi 3 Model B	Processor Broadcom BCM2387 chipset, Operating system Windows 10 IoT Cortex-A53, Inbuilt wireless connectivity, Memory 1 GB, 1.2GHz Quad-Core ARM
Arduino UNO (Atmega328 microcontroller)	Clock speed 16 MHz, Flash memory 32 kB, SRAM 2 kB, EEPROM 1 kB
DS1820 Temperature sensor	Accuracy ± 0.5 °C from -10 to 85 °C
PIR HC-SR501 Motion sensor	Sensitivity up to 7 m, Beam angle 120°
LDR sensor	Sensitivity 3 ms
Clamp sensor SCT 013-030	Opening size: 13mm*13mm, Non-linerity±3%（10%—120% of rated input current）
NRF24L01+ module	Maximum data rate 2 Mbps, 125 RF channel operation, True single-chip GFSK transceiver

The current transformer (clamp sensor) and voltage transformer method was used to measure current and voltage because this is a non-invasive method. Here the measuring circuit does not electrically connect with the working circuit, so isolation protection is ensured.

C. Communications Protocols

Three types of communication protocols were used in this project which are I^2C, SPI, and 1-wire.

I^2C – I^2C (communication is used between Raspberry Pi 3 and Arduino UNO) stands for Inter-Integrated Circuit, which is a synchronous serial interface useful for communicating with other peripheral devices. Multi-master configuration is also possible. SCL and SDA are the basic ports of I^2C. SCL (Serial Clock Line) is used to transmit clock signals, and SDA (Serial Data Adapter) is used to send data.

SPI – SPI stands for Serial Peripheral Interface, which is a synchronous protocol that allows only

one master device to initiate communication with slave devices. SCK, MOSI, and MISO are the basic ports of SPI. As this is a synchronous protocol a clock signal is needed, this signal is fed through SCK. MOSI (Master Out Slave In) is used to send data by the master. MISO (Master in Slave Out) is used to get the data from the slave.

1-wire – 1-Wire bus uses only one wire for signaling and power. Communication is asynchronous and half-duplex, and it follows a strict master/slave scheme. One or several slave devices can be connected to the bus at the same time. Only one master should be connected to the bus. The bus is idle high, so there must be a pull-up resistor present.

There is no theoretical limitation in the number of connectable devices with the above protocols. Mainly the physical limitation is the factor that governs the maximum connectable number of devices. The physical limitations are the length of the bus, capacitive loads on the bus, Electrical drive type, and Speed of the data in the bus. So practically the limitation of the number of devices is 1008, 125, and 32 respectively. I^2C allows asynchronous and needs less wire for communication, so this protocol was used between Raspberry Pi 3 and Arduino UNO. The 8-bit address was used so 255 rooms can be connected to one master device. I^2C is not well defined for wireless communications at the same time the radio module that we used (NRF24L01+) is designed for SPI protocol, so the SPI protocol was used between Arduino UNO and Arduino Pro mini. A maximum of 125 wireless units can be connected. 1-wire protocol was used to connect the digital temperature sensor with the Arduino UNO.

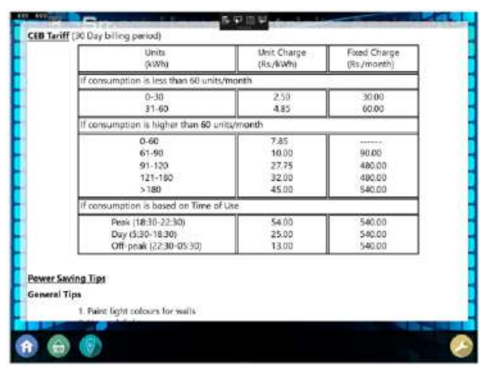
D. Graphical User Interface (GUI) Design

The GUI has consisted of four tabs those are home tab, the Room tab, the Information tab, and the Configuration tab.

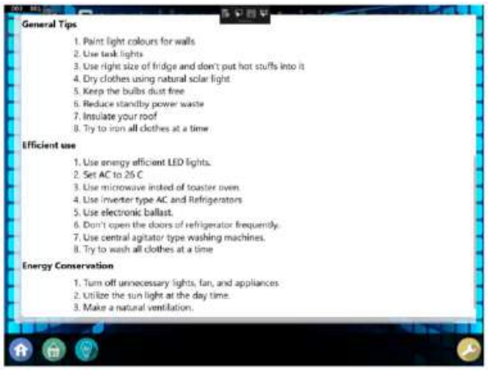
(a)

(b)

(c)



(d)



(e)

(f)

Figure 3. Smart device application tabs. (a) Home, (b) Room, (c) Inside room window, (d) Information, (e) Tips, (f) Configurations.

As shown in Figure 3, the room tab (c) can show the all rooms (Living Room and Kitchen) which have been set in the configuration tab. The living room was set with one bulb and a fan. The human detection state, light intensity, room temperature, and power consumption can be seen from the left side of the window respectively. Here all the values have been shown as zero because this GUI was not connected with the Raspberry Pi3 when the photo was taken.

The Sri Lankan electricity tariff system for domestic consumers, as well as the Time of Use (ToU) system, have been shown in the upper portion of the information tab (d). The lower part carries some tips to reduce and save energy (e). Finally, the configuration tab has the choice of connected devices inside the room (f).

4. Results and Discussion

This topic briefly discusses the clamp sensor sensitivity test, Wi-Fi module range measurements, temperature accuracy test Voltage calibration, and limitations of this project.

A. Clamp sensor sensitivity test

In this sensitivity test, an Incandescent lamp, CFL lamp, Bouth, Phone charger, and Glue gun were selected and the current through them was measured using a multimeter and using home automation application (proposed system). The readings are shown below in Table 2.

Table 2. Comparison between the digital multimeter and proposed system reading

Device	Multimeter reading (A)	Proposed system reading (A)	Error (%)
Incandescent lamp (100W)	0.440	0.435	1.1
CFL lamp (23 W)	0.100	0.098	2.0
Bouth (30W)	0.090	0.078	6.0
Phone charger	0.050	0.048	4.0
Glue gun	0.250	0.239	4.4

According to the clamp sensor sensitivity test results, we found that the error is too small and it can be negligible in the proposed system.

B. Wi-Fi range measurements

The NRF24L01 module works with the help of SPI communications. These modules can either be used with a 3.3 V microcontroller or a 5 V microcontroller but they should have an SPI port.

NRF Wi-Fi Module was tested in normal condition, with the cover condition, and with cover and walls ranges were measured. The readings are shown in Table 3.

Table 3. NRF Wi-Fi module range results

Normal condition (m)	With cover condition (m)	With cover and walls (m)
40.8	36	5.2

According to the specification in the datasheet, the NRF Wi-Fi module can work maximum range is nearly 60 m. But, using covers and obstacles it can work up to 5.2 m.

C. Temperature accuracy test

The temperature was measured using the proposed application and phone sensor. For the comparison, online weather reading was used. The results are shown in Table 4.

Table 4. Temperature accuracy test results

Application (°C)	Phone sensor (°C)	Online weather (°C)
31.19	31.18	31

Here proposed application temperature reading is more accurate than other readings.

D. Voltage Calibration

Voltage calibration for the system was done to get accurate readings. Initially, the voltage at a particular point was measured by a TM-87 digital multimeter. The voltage reading of the multimeter is 222 V. Then, again the voltage was measured in our system. Finally, the error between the multimeter and our system was reduced by setting the calibrating resistor. To obtain 222 V in transformer 47 kΩ variable resistor was used.

E. Limitations

The advantages of smart home systems are easy to understand and user-friendly, but at the same time, there is a drawback in the learning curve for most people. For anyone already immersed in technology, converting it will be a breeze, but for anyone not so tech-savvy, it makes for a lot of time spent to understand. The IoT is a diverse and complex network. Any failure or bugs in the software or hardware will have serious consequences. Even power failure can cause a lot of inconveniences.

Delay functions in the Arduino programming were used, because of excess use of delay function the I2C communication between Raspberry Pi 3 and Arduino became utterly slow. The need for the excess delay function came up due to the greater number of sensors and automation processes. Also took too much time for automation processes. As a solution, we implemented jump instruction and we removed delay functions, so the delaying process occurred when only necessary not for all executions. So, the communication became high.

Less reading resolution: The maximum value of the LM35 is 1V, but the internal ADC uses 5V as a reference, so 80% of the ADC was wasted. So, we manually set the reference voltage as 1.1V. So, we can optimize the whole resolution.

5. Conclusion

Recently, the home automation market is a very promising field that is growing very fast and needs a vast range of developments that can be carried out in the concept of the smart home. In this project, the main concept of the system is to perform the basic home automation function by using numerous sensors. The system mainly consists of control of the home appliances, reducing energy consumption, and providing awareness. Using the system public can obtain a piece of knowledge regarding the Sri Lankan tariff system. At the same time, it will motivate them to use an adequate amount of electricity without wastage. Since this system is introduced for the home appliances it can work 100% efficiency when it uses in 230V appliances.

Finally, the system helps to produce the optimum amount of electricity in Sri Lanka. In the future, a new tab window can be added for CEB, where CEB can directly communicate and share information with consumers and CEB can get the power usage of the consumers directly without visiting personally.

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