Android-Based Smart Power Outlet Switching Device Using ESP8266 Enabled WiFi Module

Dennis A. Martillano*, Rondolf G.Reyes, Ian Robert B. Miranda, and Kevin Lester C. Diaz

***Abstract*—The merging of the physical and digital worlds is the result of technological advancement and a new chapter in the story of today's networked world governed by internet. Having the advantage of merging allows changes to be adopted with respect to organization, manipulation and even control of almost anything via networked technology. This leads to the idea of Internet of Things (IoT), which can be defined as the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure. IoT is an emerging technology that can allow interconnection of everything beyond what is expected. This study aims to engage in research, modeling and implementation of an integrated technology that will blend WiFi development board modules built on ESP8266 based modules, microcontrollers and elements of Internet of Things to form an intelligent environment. The primary focus is to allow smart power outlet sources of devices to be controlled and monitored via the internet and/or local wireless area network by infusing standardized elements of IoT, communication protocols and a mobile and web application.**

***Index Terms*—Arduino, ESP8266, internet of things, green technology, WEMOS D1 mini.**

I. Introduction

Internet of Things or IoT is the intelligent network of everyday physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment [1]. Typically, Internet of Things is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications (M2M) and covers a variety of protocols, domains, and applications [2]. More than just simple hype, Internet of Things is a crucial, fundamental shift in technological advancement that dramatically impacts existing businesses, infrastructures, and even private institutions.

A specific application of IoT does not necessarily require huge implementation in an initial research but rather, a small set up that can be both achievable and impactful. In this study, the focus is on a specific department in an institution that caters the management of devices and their power outlet sources in a computer laboratory set-up. In the current set-up, personnel make sure that the devices are completely turned on when needed and turned off when not required. This study would also like to bring into line the opportunity that can be projected with the expansion and innovation that the identified institution is committing to all of its stakeholders. The physical expansion of the institution would mean the need for expanded monitoring and controlling of devices and their power sources. This sets an opportunity in utilizing existing internet infrastructure of the target institution, and incorporating Internet of Things key elements blended with mobile and web technology, and communication protocol in controlling devices and power outlet sources, anytime, anywhere thus, promoting an intelligent environment.

II. Literature Review

In order to identify the requirements, elements and the status of IoT that can help in achieving the primary goal, the study considered collecting and analyzing an overview of IoT, architectures, and vital technologies, its impact, elements, framework, use, and applications. A systematic review of literatures in [3] identifies real time needs, efficient power consumptions of applications and access to an open and inter operable cloud system as requirements in IoT. This solidifies the need that this study is aimed at. The study also suggests that IoT is a vast and such a broad concept that there is no proposed, uniform architecture [3]. However, the Open Standards that will enable IoT sets the key elements based on the IEEE P2413 Standard for an Architectural Framework for the Internet of Things Working Group [4]. Key elements were identified to "define connected things" in the study. With respect to implementation, mobile technology is the upfront medium to establish and power IoT especially in terms of automation and device and hardware control [5], [6]. This also supports the idea that mobile technology dictates the move in using portable devices through wireless networks as used in automation [7]. The studies under the area of Ubiquitous Home [8], Control Systems using Arduino and IoT [9] discuss and depict the requirements needed in technical setup, and the protocols that should be followed when developing IoT in automation and control. The discussion about Understanding the Protocols behind the Internet of Things, specifically the object notation was considered in this study since the study is geared towards a control of device that integrates elements mentioned like mobile technology, web application, and control system using microcontroller. A study utilizing different IEEE protocol [10] was also considered in order to have basis in implementing control of devices in a network environment. However, this study focuses on the use of new technology and module that utilizes 802.11 WiFi protocol infused with IoT element that can commence communication within or outside the local network environment.

Manuscript received February 10, 2018; revised April 20, 2018. This study was supported by Malayan Colleges Laguna, Philippines.

The authors are with Malayan Colleges Laguna, Philippines (e-mail: damartillano@mcl.edu.ph).

doi: 10.18178/jacn.2018.6.1.255

III. Methodology

A reformed prototyping intended for the development of projects under Internet of Things was utilized. The Modified Prototyping depended on the Nurun Procedure that takes into account the utilization of microcontrollers like Arduino in mixing it with IoT [11]. Fig. 1 demonstrates the 3-way system utilized as a part of building up the task.

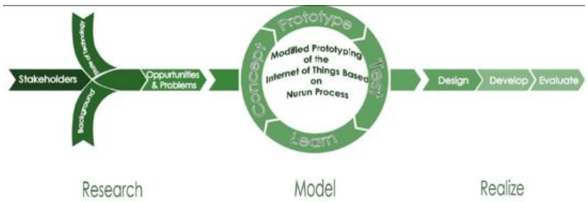

Fig. 1. Nurun-based modified prototyping for IoT.

Research. During this stage, a study was led through actual immersion to a manufacturing company in order to observe and identify the need for the project. Interviews, observations, literature and related studies were gathered and examined with a specific end goal to figure out if the system is practical.

Model. During this stage, the functionalities and the configuration of the system was figured and a working model was then created, peer tried, and analyzed for further improvements. This procedure was repeated a few times until the required system was at long last developed.

Realize. In this stage, the information from the Model stage were gathered and broken down with a specific end goal to figure out whether the study's targets have been met and if the framework was working legitimately.

A rapid, iterative process that will allow creation of concepts and learning were performed in the Model stage. This is also where reseachers build prototypes, test it with stakeholders and learning from the results. Under this process, the researchers used the Framework for the Internet of Things, which was captured from IEEE P2413 Standard for an Architectural Framework for the Internet of Things [12]. Fig 2 shows the standard elements and components that shall be included in the study.

Fig. 2. Key components of connected things for smart power.

Connected things all share five key components: the need for smarter power consumption, storage, and management; the need for security; high-performance microcontrollers (MCUs); sensors and actuators; and the ability to communicate [12]. These elements are considered in the study to provide a smart device that combines key components.

IV. Results and Discussion

The concept of Smart Power as according to the Framework mentioned was applied by allowing actual power outlet sources and light switching in two laboratories of the target institution to be controlled and monitored. Simple set-up controlled things are imposed by studies related to automation leading to smart and green computing. [13]. Fig. 4 shows the general block diagram of the system set-up of the study. The control is being performed by the circuit controller that is being triggered by the dedicated Microcontroller Unit which is the Arduino MCU, an integral part of the IoT Framework. Collectively, the study termed the actual hardware setup as Device Controller, which combines an industrial relay circuit controller and the MCU in a portable device. The remote controlling of the power outlet sources can be done by allowing communication to take place among the mobile application, the cloud server, the dedicated inhouse computer server and the ESP-8266 based WiFi module.

In this study, WEMOS D1 Mini WiFi board was utilized. The WEMOS D1 Mini is built on the ESP8266EX 32 bit RISC micro-controller powered at 3.3V and running at 80MHz. It has a full WiFi transceiver, utilizing 802.11 IEEE protocol with 64KB of instruction RAM, 96KB of data RAM and 4MB flash memory. It is light and small with approximately 34.2 mm x 25.6 mm in size with only 10 grams of weight. It also has 11 Digital I/O pins and 1 analog input pin. [14]. This WiFi module is a development board and can be programmed using the Arduino IDE. The development board can be added to Arduino IDE and be programmed using the language used in Arduino Microcontrollers. The process of connecting the WEMOS D1 board to the Arduino IDE including the web service programming can be viewed in [15], [16]. However for this study, the WiFi board was only utilized for communication. A separate dedicated Arduino Microcontroller was used to cater the actual control of power outlet switches. Fig. 3 shows the actual WEMOS D1 WiFi board used in the study.

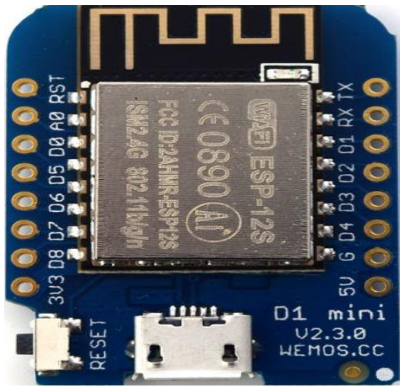

Fig. 3. D1 Mini WiFi board built on ESP8266 chip.

In the Block Diagram of the System set-up shown in Fig. 4, the WiFi Board was configured to Arduino Mega by connecting the Tx(Transmit) Pin of D1 Mini to the Rx(Receive) Pin of Arduino. The Rx Pin of D1 Mini was then connected to the Tx Pin of the Arduino respectively. This is to commence the data transmission of Arduino to D1 Mini, which is then communicated to the Server via WiFi connection. A dedicated cloud server was used to send data to and from which also acts as the central repository that allows the mobile application to send and receive commands.

Although WEMOS D1 Mini has digital I/O pins, the study used a separate Arduino Mega to control switching of power outlets. The Industrial Relay Controller circuit(which is basically a Transistor-Relay based circuit) was connected and driven by the digital pins of the Arduino as shown in Fig. 5.

In summary, the process of the set-up shall start by using the mobile application in sending commands to the cloud server. These commands will be fetched by the dedicated server in the Institution. The WiFi Module fetches the data from the server wirelessly which is then serially read by the Arduino Mega. These data are translated into commands that are digitally written as high or low signals to the Industrial Relay Switches. Although, the WEMOS D1 Mini can directly connect to the cloud server, the study aims to provide a locally hosted set-up in order to support scenarios where internet is not present and only WiFi connectivity is available. This set-up can also provide a visible control of the system via a web application that can be accessed within the institution.

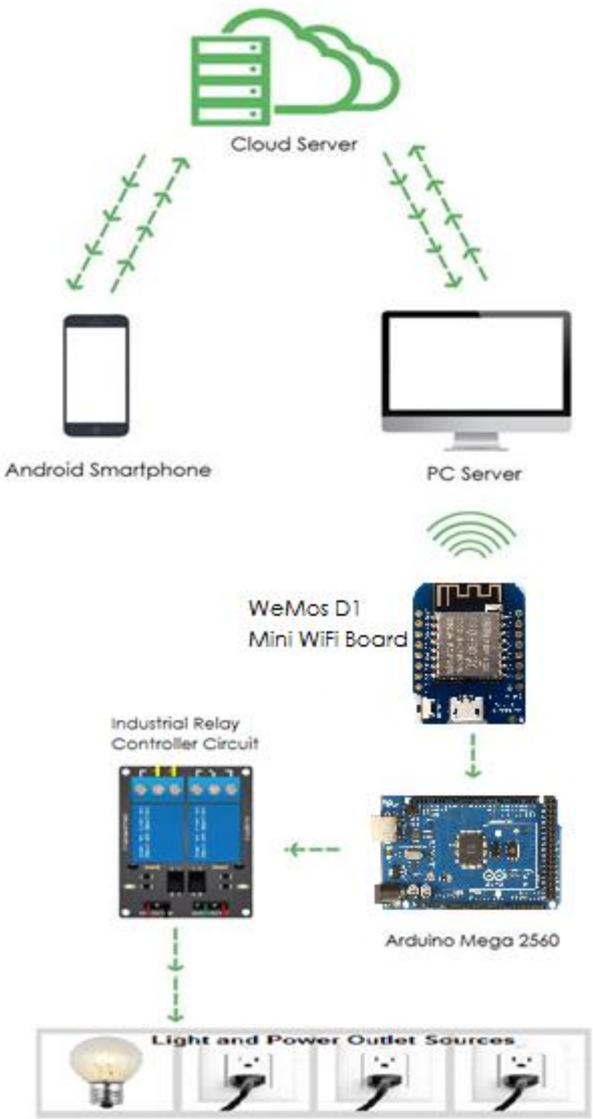

Fig. 4. Block diagram of the system set-up of smart power outlet switching device.

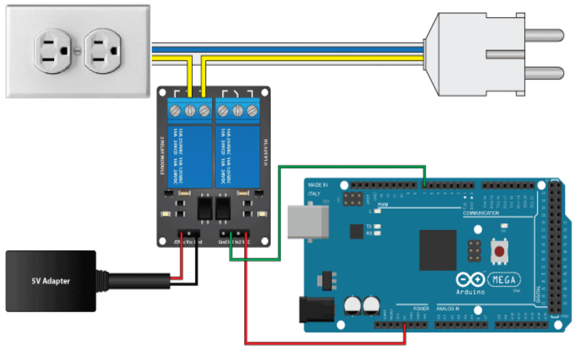

Fig. 5. Circuit diagram of industrial relay controller to Arduino mega.

A. Software Communication Set-up

The software set-up and how the whole system performs the communication can be viewed in Fig. 7. In the software set-up, the android application uses Hypertext Transfer Protocol (HTTP) class to send data through a request sent to a cloud server. The data to be sent is in form of (JavaScript Object Notation)JSON Object containing array of 0's and 1's corresponding to the array of power outlets to be controlled. The data representation of the request sent by the mobile application can be viewed in a representation as follows: {{001001},{010100},{001001},{010100}..}}. Each array corresponds to the array of power outlets to be controlled. A zero (0) value represents an off status for the device, while one (1) value represents an ON status for the device in a given array of power outlets.

Fig. 6 shows code snippet used to request sending of data in JSON format via an Android Application. A basic parsing is set within a web service application programming interface (API) in the server using PHP programming language.

Request to send Data in JSON format via Android App

```
JSONObject json = new JSONObject();
json.put("ComputerArray1", "010010");
json.put("ComputerArray2", "010010");
:
json.put("ComputerArray7", "010010");
:
//some http parameters
:
HttpClient client = new DefaultHttpClient(httpParams);
String url = "http://your_webservicephpFile";

HttpPost request = new HttpPost(url);
request.setEntity(new ByteArrayEntity(json.toString().getBytes("UTF8")));
request.setHeader("json", json.toString());
HttpResponse response = client.execute(request);
HttpEntity entity = response.getEntity();
```

JSON Parsing snippet to retrieve data via PHP

```
: // some codes to cloud server connection
$obj = json_decode($json);
:
//some code to convert retrieved
   data for comm to WEMOS
```

Fig. 6. Code snippet to send JSON formatted data via Android App and parsing and retrieval via a PHP web service API.

Fig. 8 shows the mobile application that lets power outlets to be controlled by selecting which computer (in a selected room) to be turned on or off in a given array of computer images. The array of computer images are set to match count of the data format in form of JSON as mentioned previously in this document. The JSON object is parsed in a cloud server and saved as status of each power outlet in an online database as either “on” or “off”. This is then fetched by a Representational State Transfer (RESTful) Web API using POST or GET method in a local server within the institution. The RESTful approach used in this study can also be viewed in the framework for web based smart homes [17].

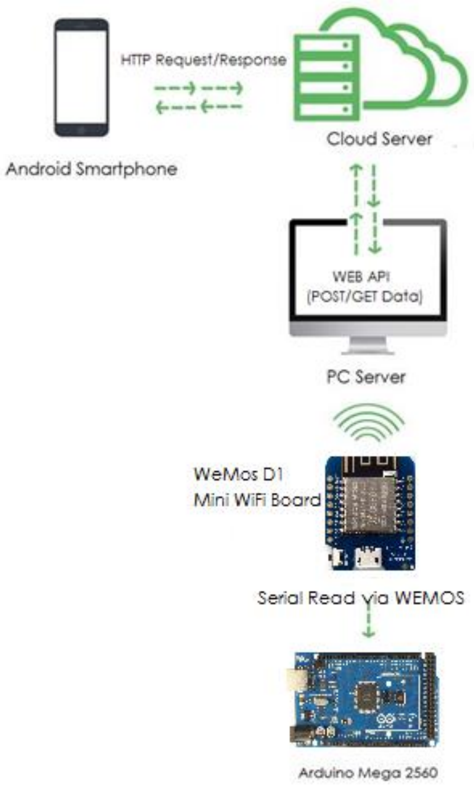

Fig. 7. Software communication set-up.

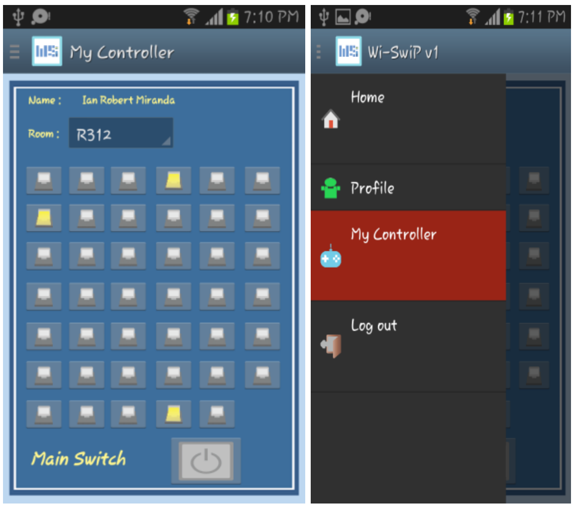

Fig8 (a) Fig8 (b)

Fig. 8. Screenshot of the actual mobile application showing the main controller (a) and menu (b) for the smart power outlets in a laboratory.

The data is then fetched and received wirelessly by a configured WEMOS WiFi Module connected to Arduino Mega. Fig. 9 shows the configuration code snippet made to WEMOS D1 using the Arduino IDE Software. These data fetched by WEMOS are converted into digital signals within the Arduino Microcontroller that literally sends high or low value to the output pins in the microcontroller and eventually turns Industrial Relays into its high or low state values. This in turn controls the device power outlets in a specific computer laboratory room.

Code Snippet WEMOS D1

```
#include <ESP8266WiFi.h>
#include<ESP8266HTTPClient.h>

const char* ssid = "your_ssid";
const char* password = "your_password";
const char* host = "your_host";

void setup() {
 Serial.begin(9600);
 WiFi.mode(WIFI_STA);
 WiFi.begin(ssid, password);

 while (WiFi.status() != WL_CONNECTED) {
  delay(500);
 }
}
void loop(){
 ConnectToWebService();   //call to webservice
 :
 //some codes for initialization
}

void ConnectToWebService()
{
   // Use WiFiClient class to create TCP connections
   WiFiClient client;
   const int httpPort = 80; //your port here
   if (!client.connect(host, httpPort)) {
    Serial.println("connection failed");
    setup();
    return;
   }
   HTTPClient http;
   http.begin("http://yourPhpWebserviceHost");
   http.GET();

  // Read response from server to retrieve data
  while(client.available()){
   :
   //some codes to parse retrieved data from webservice API
   String line = client.readStringUntil('\r');
   :
   //some codes to serially write the data through WEMOS Tx
   to Arduino Rx for digitalWriting of output

  }
}
```

Fig. 9. Code configuration for WEMOS D1 Mini.

V. Conclusion and Recommendations

The use of a WiFi module that utilizes an IEEE Protocol can provide a lot of means to commence device to device communication. In this study, WEMOS D1 Mini was used and configured to communicate in an online network environment. Integrating this with IoT elements and platforms such as mobile device can create an intelligent environment that can expand the control of things in a given institution. Guided by the framework provided by the Open Standard of IoT, the researchers were able to combine key components and elements of IoT. The study combined Actuators in form of circuit controllers, Microcontrollers through the Arduino Mega and the Communication through D1 Mini and Mobile Application via Internet. Collectively, the whole set-up provides smart power and control of "things" that can eventually lead to Green Technology. This study can be further improved in such a way that the control can be extended not only to on-off capabilities but with actual device functionality. Also, given that the WiFi Board used in the study can be configured to connect to more network infrastructure, the study can be extended by allowing an ecosystem of WiFi Modules configured in a wider or Network Farm, thereby extending also the control of things in a bigger environment. The conceptual model of the study can be further improved to allow different devices other than specified in the scope of this study in order to promote an ecosystem of intelligent things in the institution. This can serve as a venue to commence projects in IoT and Green Computing that can be impactful in the institution and the society as a whole.

ACKNOWLEDGMENT

This study was conducted at Malayan Colleges Laguna in Cabuyao City, Laguna, Philippines through the supervision of the Laboratory Management Office.

REFERENCES

[1] G. Kortuem, F. Kawsar, D. Fitton, and V. Sundramoorthy, "Smart objects as building blocks for the internet of things," *IEEE Internet Comput*, vol. 14, pp. 44-51, 2010.

[2] *Taiwan Information Strategy*, Internet and E-commerce Development Handbook, IBP Inc., 2016, p. 71.

[3] S. Madakam, R. Ramaswamy, and S. Tripathi, "Internet of things (IoT): A literature review," *Journal of Computer and Communications*, May 2015.

[4] *Standard for An Architectural Framework for the Internet of Things (IoT)* IEEE P2413, September 2016.

[5] S. Panth and M. Jivani, "Home automation system (HAS) using android for mobile phone," *International Journal of Electronics and Computer Science Engineering*, vol. 3, 2013.

[6] D. Javale, M. Mohsin, S. Nandanwar, and M. Shingate, "Home automation and security system using android ADK," *International Journal of Electronics Communication and Computer Technology*, vol. 3, pp. 382-385, 2013.

[7] L. Jin-Shyan and W. Yuan-Ming, "Experimental evaluation of ZigBee-based wireless networks in indoor environments," *Journal of Engineering*, vol. 2013, no. 286367, p. 9, 2013.

[8] R. Piyare, "Internet of things: Ubiquitous home control and monitoring system using android based smart phone," *International Journal of Internet of Thing*s, 2013.

[9] C. Doukas, *Building Internet of Things with the Arduino*, vol. 1, 2012.

[10] VishwakarmaI and D. Dharmistha, "IEEE 802.15.4 and ZigBee: A conceptual study," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 1, no. 7, September 2012.

[11] Turin. Prototyping the Internet of Things with Nurun and Arduino. June 2014.

[12] O. Logvinov, IEEE P2413 Standard for an architectural framework for the internet of things working group. [Online]. Available: http://electronicdesign.com/communications/open-standards-will-enable-iot-s-growth

[13] S. Shinde, S. Nalawade, and A. Nalawade, "Go green and save energy," *(IJARCSSE) International Journal of Advanced Research, in Computer Science and Software Engineering, Green Computing*, vol. 3, p. 1, 2013.

[14] WEMOS.cc, D1 mini A mini wifi board based on ESP-8266XX. [Online]. Available: https://wiki.wemos.cc/products:d1:d1_mini

[15] Jainrk. Programming the ESP8266 WeMos-D1R2 using Arduino software/IDE. [Online]. Available: http://www.instructables.com/id/Programming-the-WeMos-Using-Arduino-SoftwareIDE/

[16] WEMOS WebSever example [Online]. Available: http://www.esp8266learning.com/wemos-webserver-example.php

[17] A. Kamilaris, V. Trifa, and A. Pitsillides, "HomeWeb: An application framework for web-based smart homes," in *Proc. 2011 18th International Conference on Telecommunications (ICT)*, 2011.

Dennis A. Martillano is a graduate of bachelor of science and computer engineering from STI College Southwoods. He has units in mathematics from the University of the Philippines and a master's degree holder in information technology and a graduate degree holder in distance education also from the University of the Philippines. He is currently taking up his doctor in information technology where he is specializing medical data mining in Technological Institute of the Philippines. Currently, he is teaching in the College of Computer and Information Science at Malayan Colleges Laguna Philippines. Among his research outputs are in the area of machine learning, internet of things and alternative learning solutions.

Rondolf G. Reyes studied bachelor of science in information technology and also specialized in cisco networking at MCL. During his on-the-job training at TeleTech Sta. Rosa he practiced and applied his knowledge and skills on networking by planning and setting up a small network which included cabling, subnetting, troubleshooting computer hardware He has knowledge in developing web and mobile applications. He is also a member of junior philippine computer society (JPCS). He is currently working in national research council of the Philippines as a science research specialist I

Ian Robert Miranda studied bachelor of science in information technology at Malayan Colleges Laguna. He also joined a student organization called JPCS-MCL chapter which stands for Junior Philippine Computer Society, an organization of CS and IT students which help promote socialization and teamwork among each other. He specialized in cisco network and plans to take the CISCO certification exam in the near future for his work.

Kevin Lester C. Diaz studied bachelor of science in information technology specialized in cisco networking at Malayan Colleges Laguna (MCL). His passion for networking helped him also to earn money from his customers who needed assistance with their internet connectivity and network set up. Currently, he is connected to a unit in HP in United States of America as a web developer