Integration of NFC Technology on Household Appliances

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Abstract—**The study focused on developing a system that would monitor the usage of appliances in dormitories. This appliance management system will allow dormitory owners and tenants to utilize and to check how much power each tenant consumes per appliance, as well as the overall power consumption. Not only will the tenant learn how much energy he/she has consumed but the owner will also know its equivalence in terms of money. It includes a pre-paid and post-paid payment system. The project focused on expanding the usage of near field communication in terms of establishing smart connections between the user and all the electrical appliances inside a dormitory. The group also used MyRio microcontrollers in handling the operations on the entire system where connectivity, sharing and measuring information, and computations are concerned.**

Index Terms—**Mobile App; MyRio Microcontroller; NFC; Wifi.**

I. INTRODUCTION

Dormitories have been used as a convenient temporary shelter for those whose schools or workplaces are a great distance away from their homes. Most college students that live farther from their campus stay in dormitories that are near the vicinity of their respective campuses. The payment or rent of rooms in dormitories depends on the amenities a lessee will be using, and prices increase when adding more appliances [1]. With the amenities priced at a fixed rate, it raises concern on how much the amenity has been used with discrepancies in how much is actually paid for. It can vary according to how many tenants stay in a room. This presents problems in terms of the usage of electricity and how the lessor can monitor the usage of each of the tenants, as well as a problem in terms of the usage of electricity between the different tenants, the amount they consume, and what they actually pay for. Our system aims to solve the problem in dividing the electricity bill because each tenant will now have a balance or pre-paid type of electricity bill. This will also eliminate the use of illegal sub-meters in some of the dormitories here in our country. Our system aims to resolve the issue on the billing and usage discrepancies by comparing the data from our system and the billing statement.

In recent years, there has been a great rise in NFC technology. NFC provides a secure connection for data transfer and synchronization. Examples of this are cashless transactions and device-to-device pairing. With the growing use of Wi-Fi and Bluetooth enabled devices, transferring files are getting better and more efficient. Controlling devices using mobile phones are also getting better. With the help of NFC technology, the connecting, detecting, and syncing/pairing of these devices (and using them for other various applications) are simpler and quicker.

The work done by Home Automation using Raspberry Pi through Siri Enabled Mobile Devices [2] constructed a low cost home automation system using Raspberry Pi which is controlled using voice automation from an iOS device. The system voice recognition is dependent on the iOS devices Siri features capability to recognize speech.

The work done by Home automation system for energy management through power lines [3] constructed a microcontroller based home automation system that communicates with the user through power lines. The user can check his/her consumption through the LCD screen on the fixed or stationary device.

The work done by Microcontroller-based Power Monitoring and Switching Device for Appliances over a Zigbee Network [4] constructed a system that communicates using Zigbee for communications and PIC microcontrollers. It focuses on the incorporation of an ammeter and voltmeter to compute for the power.

The work done by LabView-based Voice Activation System for Switching Home Appliances Utilizing Audio Fingerprinting Algorithm [5] aims to create a voice-activated home automation system to control appliances by turning it ON and OFF.

Our study is interested to apply NFC to give better power/energy consumption monitoring for dormitory rooms. The device pairing involves the private access of each appliance through a particular smartphone where it also shares the power meter and privatizes each smartphone to the owner/user. The cashless transaction is applied in the prepaid use of each appliance. It will be implemented in at least 4 common dormitory appliances to work with NFC and Wi-Fi Technology for operation and power monitoring.

MyRio will be the main processor for the system and will serve as a wirelessly-controlled switch. The microcontroller programming was done using LabView.

The system will utilize an application that can compute for the overall and individual power consumption of said appliances by using an algorithm in the app which can be viewed by both the lessor and the lessee. It will use the information to start and stop the operation of the appliances by using the NFC tags to activate or deactivate the appliance. The application will store and display remaining power balance of the lessee and the corresponding appliances accessible to the lessee. It can also use either a prepaid or postpaid service in monitoring the power consumption of the electrical appliances.

II. INTEGRATION OF NFC TECHNOLOGY IN HOUSEHOLD APPLIANCES

Since living in dormitories has been a trend for students to have easier access to schools or professionals staying near their workplace, dormitory owners need to further monitor how the occupants consume their electricity. We are proposing to build a system wherein NFC tags are integrated on the appliances inside the dormitory such as the television, air conditioning system, microwave, oven toaster, water heater, electric heater and other devices that use electricity. We would be creating an Android application where power consumption for each appliance would be seen in the app. Each occupant will have a NFC enabled android device so that they could use it to pair and activate the appliance that they want to use so that only he/she can use it and so that he could monitor his own power consumption so that it would not reach the maximum power allocated to him.

The diagram in Figure 1 shows the system integration of the main components of this prototype. It shows where each part is connected in the system. The figure also gives a general perspective of the materials used in this project. This diagram shows how the microcontroller is the center of the system then it shows how to other components like the relay, database, and the wireless connections are connected.
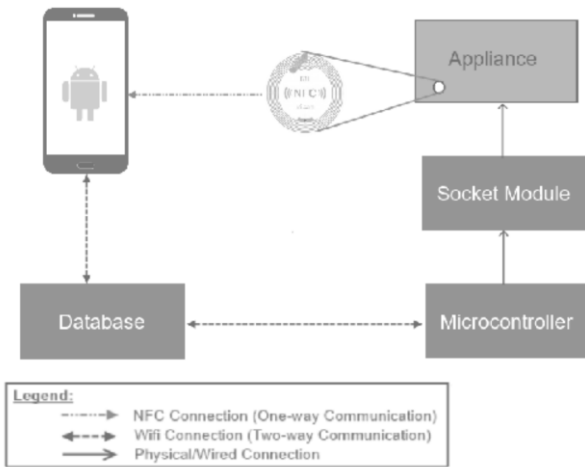

Figure 1: System Block Diagram

A. Hardware

The hardware of the system mainly involves the socket module. Figure 2 illustrates the design and schematic diagram of the socket module. The socket modules diagram graphically demonstrates how the 220VAC socket connects to the relay which is connected to a plug that the appliance will be plugged into. The diagram also shows the microcontroller is controlling the relay but since the microcontroller can only put out a maximum of 3.3V a step-module is required. The step-up module converts the 3.3V output of the MyRIO to 5V this is necessary for the relay circuit to detect the high logic shift. This circuit is vital for turning the appliances on and off as directed by the user. This circuit is mainly responsible in switching the electricity on and off to the appliance.
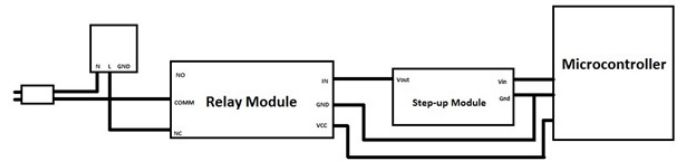

Figure 2: Socket Module's Schematic Diagram

MyRIO is a real-time embedded evaluation board that is used to develop certain applications using its key features such as its onboard FPGA and microprocessor. For this study, the group utilized the MyRIO into a wirelessly-controlled switch. The devices programming was done using the program called LabView. The device's software was divided into two parts: A system that will enable the MyRIO to continuously collect the table from the database and export it to each myRIO. The group utilized an open-source toolkit named LabSQL which enables blocks that can connect, disconnect, create/delete database and tables, and send queries to the database as well as retrieve the queried data.

A system that will handle the data imported will enable the MyRIO to supply a voltage output through a specific port. It must be able to isolate the needed columns and read the value of the row assigned to the specific appliance. The group also configured one of the MyRIOs LED (LED 0) to serve as an indicator to let the user determine whether the state of the output of MyRIO is HIGH or LOW. Proper configuration of the MyRIOs Wi-Fi or network connectivity was also used to enable the MyRIO to connect to the database. For the hardware component of this system, the group assigned three pins, particularly pins, DIO 0, 5V, and DGND as the pins that will be connected to the socket module. DIO 0 is designated as the digital output that will supply a 3 Volt input to the socket module. The pins that are labeled as 5V and DGND will serve as the VCC and GND, respectively.

The socket circuit was modified to turn the residential electrical socket and be compatible to the microcontroller. It mainly composes of the power relay, electrical socket and the microcontroller. The power relay acts as a switch and has an input voltage of 250VAC and an output of 5VDC at maximum current of 10 amperes. The live wire is connected to the normally closed port of the relay and the input pin of the relay to the micro controller. When a 5 volts power is detected the electrical socket turns on the electricity and when there is no 5 volts power, the electricity is turned off.

B. Database Set-up

The type of database used was the MySQL database and used phpMyAdmin as the host server for this system. The database was created through the use of phpMyAdmin, and the corresponding table assigned for each user. The database contains the appliances available to the user, the status of said appliances, power consumption and its peso equivalent, and the corresponding times that indicate the activity of the MyRIO device.

Table 1 shows the main data to be retrieved and written by the android application to control the use of the appliance. The myrio number indicates the primary key. The MyRIO status indicates the status of the MyRIO device, indicating whether it is on (1) or off (0). The appliance column shows the available appliances of the user. The permission column shows the available appliances that can be used by the user that was granted access by the admin.

Table 1
Columns 1-4 Of User Table In MYSQL Database

myrio_number	myrio_status	Appliances	Permission
1	1	Microwave	allow
2	1	Television	allow
3	1	Electric fan	allow
4	0	Air-conditioning	block

In Table 2, the key columns presented are used in computing the power consumption at a given time consumed by the appliance. Time start indicating the timestamp when the appliance is turned on and time end indicating the timestamp when the appliance was turned off. The total duration is the difference between the time start and the time end.

Table 2
Columns 5-7 Of User Table In MYSQL Database

time_start	time_end	tot_duration
13:56:17	21:49:31	7:53:14
1:11:33	21:50:28	20:38:58
1:09:31	21:48:01	20:39:30
1:08:31	21:51:30	20:43:01

The calculation of the power consumption and its equivalent amount is calculated with the aid of the values given in Table 3 in the database. The power rate and the peso equivalent are constant, but can be changed by the admin. The power rate was based on the wattage of each appliance, given in the table in watts instead of kilowatts. The peso equivalent was based on the power rate given by Meralco on February 2017 which is at PhP8.82 per kWh. The consumption is calculated by multiplying the total duration with the power rate. The amount due is acquired by multiplying the consumption with its corresponding peso equivalent. The amount paid is the credit given by the admin to the user (in Peso).

Table 3
Columns 8-12 Of User Table In MYSQL Database

power_rate	peso_equiv	consumption	amount_paid	amount_due
1200	11	9.6	100	105.6
80	0.7	1.68	100	1.18
50	0.5	1.05	100	0.53
1200	11	25.2	100	277.2

C. Mobile Application

The group considered to design Android Apps as the user interface system of this thesis. The android apps will be used to view data and to switch household appliances ON/OFF. Considering the data from the survey conducted last year, the android app will require Android phones to at least have an Application Program Interface (API) level of 19 (Kitkat) since most of the Android phones being used by the respondents have an API level equal to or greater than 19.

Every android app has a file called AndroidManifest.xml [6]. This file is used by the application to ask permissions from the Android phone to use its components or subsystems. This is also the file where all Java packages being used by the application are. This file also contains all the names of icons and the labels, libraries, instruments and intents that the application requires.

The Administrators app uses this file to ask for permission to use the phones Wi-Fi Adapter and to hold all the Java packages needed to run the system. The XML files are used by the group to design the layout of the application. Through this, the group was able to add text, buttons, backgrounds, and other functional aesthetics to the application. The java files of

every application is used to specify which action the user or the programmer wants the application or a specific activity of the application to perform. In this application, the group used java to program the buttons to open a certain activity, to change the status of a specific tenant's access to the system, and to increase the number of allotted hours that the tenant can use the system. Java was also used to display the data from the database.

There are different activities/pages available. This will allow the administrator to do the following:

1. displays the list of features or options that the administrator can choose to do
2. view every detail about each tenants power consumption including the his/her current balance
3. choose to restrict the users access when the user has either unauthorized access, or grant the user access once the administrator allows the tenant to use the system
4. give additional hours to the tenants usage when he/she has paid for additional hours of access
5. allows the administrator to edit the power rating of each appliance

The Tenants app just like in the Administrators version of this app also has a file called AndroidManifest.xml. The Administrators app uses this file to ask for permission to use the phones Wi-Fi Adapter and NFC adapter, and to hold all the Java packages needed to run the system.

It also contains the names of the intent filters being used by the application to aid its foreground dispatch system. The XML files were used by the group to design the layout of the application. Through this, the group was able to add text, buttons, backgrounds, and other functional aesthetic to the application. The group also created a new xml file which contained the tech-filters for the NFC based functions in the application. The java files of every application is used to specify which action the user or the programmer wants the application or a specific activity of the application to perform. In this application, the group used java to program the buttons to open a certain activity, to change the status of a specific appliance through the database to turn them ON/OFF, to view the current balance of the tenant and the amount that he/she has to pay the dormitory, view the list of appliances that are currently being used and on standby, and the details about the users total consumption. Java was also used to convert the user's consumption which is in terms of kilowatt per hour - into their monetary equivalent.

D. NFC

The decision to use NFC instead of other wireless methods for the pairing of the module to the phone is because of the security that comes with NFC. Because of its short range, it is better for pairing an immediate set of devices. More phones now have NFC modules built in because of the steady rise of the use of NFC technology with contactless banking and transactions.

Using a third party NFC based mobile application, the NFC enabled phone (Tenant) was tapped to read the tag. Then, the group timed and recorded the response time of the application in detecting the tag. The group repeated the first two steps using the created application. After this, the group turned OFF all appliances. The next process involves the systems response. By putting the phone in close proximity with an NFC tag, the group measured the amount of time for the appliances to be turned ON. The data was also recorded.

With the appliances turned ON, the group measured the amount of time of the entire system to turn OFF the appliances. All functions of the tenant's app were tested by comparing the values and data presented in the app with the data in the database. In the administrator's app, the group tested the apps ability to grant access or to remove the tenant's access to the system. All appliances will be turned OFF and cannot be turned ON once the tenant's access is removed. The feature that allows the admin to update or edit the power rate of each appliance was tested and recorded. The feature that allows the admin to give the user more credit or time to access the system was also tested and recorded.

III. TESTING

A. NFC Detection and Switching Testing

The group successfully used the NFC tag and phone to trigger the MyRIO device to allow or block current flow of the socket to enable or disable the use of the device. Through the use of the phone application, the device was able to read the content of the tag, or the name of the appliance, and send a 1 or 0 value to the database to trigger the MyRIO device. The time it takes for the phone to read the NFC tag and to send the 1 or 0 value to the database was recorded and the results are shown below. 10 trials were conducted on each of the socket modules. The response time was measured to have an average of 1.896 seconds to turn ON the appliances and 1.883 seconds to turn OFF the appliances.

The distance the phone can detect and read the NFC tag was measured at a maximum of 1.5 centimeters.

B. Android Application

For the computation of the individual power consumption, a formula within the app was used. A trial was conducted using the time given in Table 2. The data was computed manually and compared with the data computed by the Android App are shown in Table 4.

Table 4
Power Consumption

Appliances	Power Consumption Manual Calculations (in kWh)	Power Consumption App Calculations (in kWh)
Microwave	9.4596	9.6
Television	1.6506	1.68
Electric fan	1.0317	1.05
Airconditoning	24.84	25.2

The consumption calculated manually and the consumption calculated from the app differs only by a small fraction. This is mainly due to the rounding off of values. Another trial was made in order to show how it would be viewed in the GUI of the application shown below in Figure 3.

C. Charging of Tenants

For the software component of the system, the computing of the time until the state of the socket module is OFF using the value of the amount due of the user in the android application was tested. The tests conducted were run in 5 trials. For each trial, an amount was sent to the database to test the prepaid capability of the system. Once the amount indicated in the amount_due column is equal to or greater than the amount indicated in the amount_paid column, the value of the myrio_status column switches to 0 for the

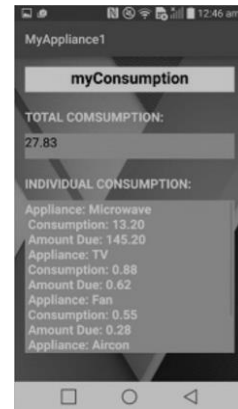assigned socket module, thus turning off the socket module, blocking access to the appliance.

Figure 3. Screenshot of the myConsumption activity in the android app

Table 5
Prepaid trial of Microwave with an input amount
of 1 Peso.

Trial	Calculated time until OFF	STATUS = OFF?	Time measured until OFF (minutes)	Percent Difference
1	0:05:27	SUCCESS	0:05:30	0.9132%
2	0:05:27	SUCCESS	0:05:30	0.9132%
3	0:05:27	SUCCESS	0:05:30	0.9132%
4	0:05:27	SUCCESS	0:05:30	0.9132%
5	0:05:27	SUCCESS	0:05:30	0.9132%

Table 5 shows the results where the input amount per trial is 1 Peso. The microwave was ON for an average time of 5 minutes and 30 seconds, and had switched to the OFF state after the condition of the amount due was reached. There is a difference between the calculated time and the time measured due to the response time of the socket module being taken into consideration. The percent difference was calculated at an average of 0.9132%. In Table 6, the input amount per trial was increased to 10 Pesos. The microwave was ON for an average time of 54 minutes and 37 seconds for every trial, with similar results to the previous test, having an average percent difference of 0.1099%.

Table 6
Prepaid trial of Microwave with an input amount of 10 pesos

Trial	Calculated time until OFF	STATUS = OFF?	Time measured until OFF (minutes)	Percent Difference
1	0:54:34	SUCCESS	0:54:37	0.1099%
2	0:54:34	SUCCESS	0:54:37	0.1099%
3	0:54:34	SUCCESS	0:54:37	0.1099%
4	0:54:34	SUCCESS	0:54:37	0.1099%
5	0:54:34	SUCCESS	0:54:37	0.1099%

D. Endurance Test

When the system underwent an endurance test, the air conditioner was plugged into the socket module for 8 hours and the electric fan was plugged for 48 hours per trial. The air conditioner has the largest power consumption out of all the appliances that we tested. The test was done at room

temperature and the wirings and the relay stayed at normal room temperature even after the endurance test. No problems were encountered during the test.

E. Fail-Safe Protocol Test

During this test, the entire system and the appliances were turned ON. When the plug(s) connected to the socket modules were unplugged, the LabView VI in the database computer could not ping the MyRIOs and automatically change all the statuses of all the appliances to OFF and stopped the charging process. All modules underwent 5 trials and resulted in the same output, successfully sending a 0 value to the database. This test was done to ensure that the tenants will not be charge unnecessarily.

F. Final Test

The application is able to turn the appliance on/off with less than 2 seconds of delay. The application is also able to acquire availability of an appliance to the assigned user, as well as the consumption of each appliance with near accuracy, only having an offset due to rounding off of values.

IV. CONCLUSION

The project has utilized four dormitory appliances as test appliances, namely, microwave, television, electric fan, and air conditioner. It was able to pair these appliances through the use of the socket module and NFC tags to the NFC enabled smartphone. The Wi-Fi is used for the communication of the database to the android application and vice versa.

Two Android applications was developed that can compute for the overall and individual power consumption of the tenant. The applications have successfully displayed the tenants power consumption on both the application of the administrator/owner application as well the application of the tenant. The applications have displayed the current and/or remaining balance of the tenant as well as the list of corresponding appliance that the tenant has access to. All data was stored in the systems database which can only be accessed and configured by the lessee using the tenant's version of the android app.

The system developed has successfully implemented the ON/OFF switch of the test appliance using the NFC tags and the NFC capable android phone using the application created for the Tenant.

In summary, the group has successfully developed a system that would monitor the usage of appliances in dormitories by developing a system that acts as an accessory for each appliance. This project uses NFC as the pairing method to and from the appliances and uses Wi-Fi as means of communication between the microcontroller and the database. This is also paired with an Android app in which the lessor can change the cost of the power being used by the lessee.

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