LOW COST CONTROL UNIT (LCCU) FOR MONITORINGSINGLE APPLIANCE POWER CONSUMPTION BASED ON IOT PROTOCOLS

[1]ABDULKARIMALBANNA, [2]NAWAF ALI, [3]ALI MAQOUSI, [4]GHASSAN ISSA

[1,2,3,4]Faculty of Information Technology
University of Petra
Amman, Jordan
E-mail: [1]abanna@uop.edu.jo, [2]nt.ali@uop.edu.jo, [3]amaqousi@uop.edu.jo, [4]gissa@uop.edu.jo

Abstract - Power consumption is globally considered to be a major concern. Many attempts to manage and control power consumptions were proposed. The paper presents an affordable system architecture capable to control, manage and track power consumption for single appliance to help low income households. The main objective of this unit is to provide households with real time information about a home appliance's consumption through fast, secured IoT gateway.Users are capable to utilize any web enabled device to monitor the power consumption and control the operation of those appliances. The paper illustrates and explains the proposed system architecture for the appliance controller. A prototype has been developed to validate the proposed system architecture demonstrating a considerable potential for using IoT platforms forsmart home systems.

Keywords - IoT, LCCU, Smart Meters, Power saving, Smart cities

I. INTRODUCTION

Power sources availability around the globe such as oil and gas is not equally distributed. Most of the domestic electricity is being consumed by heating equipment and air conditioners andhouseholdresidence do not know the exact power consumption for each appliance. Being aware of power consumed by each appliance will help controlling and monitoring total bill paid for electricity, which will eventually help household members to wisely consume power and save money. Costly Smart Meters (SMs) are capable of measuring domestic consumed power in real-time[1][2].

They read voltage and frequency and securely transmit these reading to users. A SM system consists of communication infrastructure and control devices. These meters will notify users about the consumed power via sending alerts, statistics, suggestions, and graphs. The average cost of SMis around$400 . Majority of home owners cannot install this kind of system because it is relatively expensive. Most of available SMs does notuse the concept of Internet of Things (IoT).

When facilitating IoT concept, malfunctioning appliances, that consume large amount of electricity, can be detected. Furthermore, information about the power consumed can be sent to a server, which in turn can inform users with right credentialsabout these appliances, and what actions need to be taken accordingly [3][4].

The Structure of this paper is organized as follows: section 2 literature review, section 3 proposed system architecture and components, Section 4 evaluation of proposed architecture, section 5 presents the conclusion & future work.

II. LITERATURE REVIEW

The current system for power consumption monitoring in Jordan is Primitive and calculations must be done manually at the end of pay period.Residents must wait for the next pay period and compare it the previous month bill to obtain the amount of consumed power. SMs are electronic measurement devices used by utility service providers to communicate information for customers, and to operate their electric systems attached to the traditional meters. However,their services are not available online.

These meters has many disadvantagessuch as the lack of privacy for one's power consumption whichis available to anyone to look it up and know your amount consumed.one can manipulate the power consumption because there is no security with these meters.AvailableSMsareused in calculatingtotal consumed power for homes[5].

In IoT, each connected appliance considered as a thing[6][7]. The logical representation of appliance in IoT platform , A unique IP address is assigned to this appliance to be able to communicate through IoT protocols such as MQTT, CoAP, AMQP[7][8].This communication should be secure, so all IoT platforms should provide secure communication channel through x.509 certificate. IoT platforms generate certificates and download them to the appliance(thing), and these certificates must be active before the communication starts. Certificates are used to authenticate appliances with IoT platform.

The policies' engine is a very important component in all IoT platform,which are used to authorize appliances to be able to perform specific functions such as subscribing and publishing to IoTplatform.

IoT platform provides a rule engine to enable user setting up rules for the appliances.When a matching message is received, the rule engine take action(s) and forward it to the appliance. P.Gopi [9]in his proposed systememployed a web cam for better functionality to observe the home environment.Appliances are connected to a webserver through http protocol, the appliance will turn OFF automatically when a prespecified threshold value is reach.Authenticated users can control appliances through web interface which send command to raspberry PI 3 microcontroller.Gopi'sproposed system does not utilize IoT protocols, it uses http, which generates a network overhead. Balikhna et. al.[10]proposed a system architecture for SM system that monitor and control electricity usage at residential buildings.The systemconnected to Amazon Web Services (AWS) IoT platform through system base station which includes: IoT gateway,appliance tracker, base station processor and datarepository. A drawback for such system is the system installation burden that needs to be carried out for every appliance added.Ali et. al.[11] proposed a device called Clicker.This device reduces the overall cost of hiring manpower in big organizations such as governmental institutions and universities.Appliances can be controlled(ON/ OFF) by an operator through the use of AWS IoT platform.No appliance's rules have been proposed, so the appliance cannot take action(s) according to a certain appliance's rule.The work described in this paper aims to develop Low Cost Control Unit (LCCU) device connecting the appliance to the power source. The LCCU isconnected to IoT platform, enabling the device to calculate the power consumed instantly and send it back to IoT platform throughouta set of predefined IoT protocols.These protocols will guarantee performance and the network overhead reduction. The proposed system architecture will provide users instant monitoring of power consumption when connected online from any internet enabled device.
The proposed system is scalable,capable of handling huge number of devices and message communications. the proposed system will provide secured communication between devices that cannot be interrupted, and it will help users improve power consumption. In addition to being able totrack and communicate with all your devices all at the same time.

III. PROPOSED SYSTEM ARCHITECTURE AND COMPONENTS

Theproposed LCCU for a single home appliance will use IoT platform as back-end. The system consist of the following components: IoT communication port, Appliance microcontroller board, IoT platform LCCU procedures, household mobile interface.Thefollowing subsections provide more details about each component.

3.1. IoT Communication Port(IoT-CP)

The IoT-CP is a multi-threaded communication channel component responsible for sending and receivingdata from LCCU IoT platform deployed procedures.Figure 1 presents the IoT-CP. This component will specify how the appliance can communicate securely with IoT platform using unique ID to prevent any interruption by a third party.

To ensure secure communication, a 509x certificate is configured and activated through IoT platform is installed to the LCCU. The following activity diagram shows the configuration for this component.The IoT communication port works with MQTT and CoAP protocols.

3.2. Appliance Microcontroller Board

This component consists of two modules:

a. Hardware module: that includes the following parts:

- Low cost Node-MCU microcontroller ($7).
- 20A current sensor.
- Relay module is the third part having the following features

o The relay channel can drive up to 10A @28VDC
o 5V supply voltage / input signals
o Jumper to select high/low
o Equipped[12] with a high-current relay (10A @ 28VDC)
o 2x LEDs that show the current state of the relay

Figure 1 shows the Relay module, while Figure 3 shows the hardware module.



Figure 1: Relay module

b. Software module: In this module, the appliance power consumption is calculated depending on a current sensor's analog data. Data is sent to IoT platform through IoT-CP. Two algorithms have been proposed in this module, first algorithm to get peek to peek voltage, and the other one to calculate total appliance consumption in KWH.

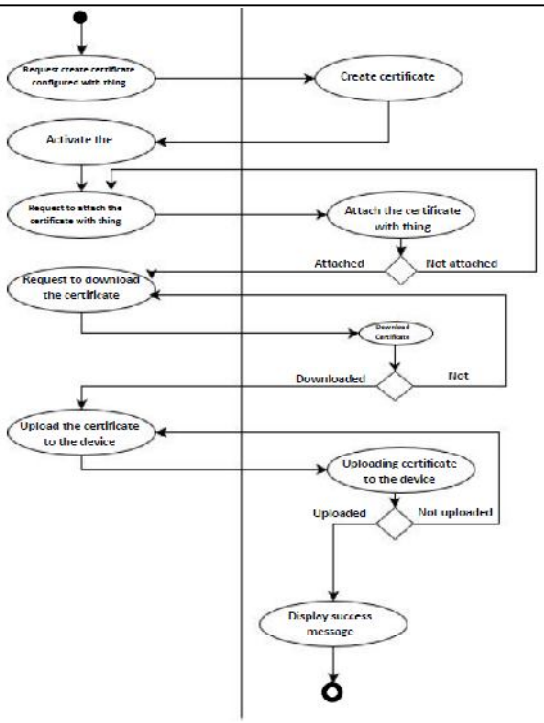


Figure 2: IoT communication port Configuration.

The following are the two algorithms:

Algorithm-1: get peek to peek voltage
Input: analog value
Output: value of peek to peek voltage

```
While (Date.now ()-startTime < 1000)
{
   ReadValue  ← anloge.read ()
If (readValue > maxValue)
                maxValue ← readValue
        If (readValue < minValue)
                minValue ← ReadValue
        Result ← ((maxValue – minValue )*5)/1024
Return result
}
```

Algorithm-2: Calculate power consumption

Input: voltage peek to peek from getVpp() function
Output: power consumption

```
Loop ()  {
ExecutionTime ← (Date.now() – startTime)/1000
        Voltage ← getVpp(analog)
        Vrms ← (Voltage/2)*0.707
        Amprms ← (Vrms*1000)/mvperAmp
Watt ← Amprms*Vrms
        Kws ←Watt/1000
        sumKws ← sumKws+kws
        Kwh ← sumkws/1000
        Sumkwh← sumkwh+ Kwh
Return Sumkwh
}
```

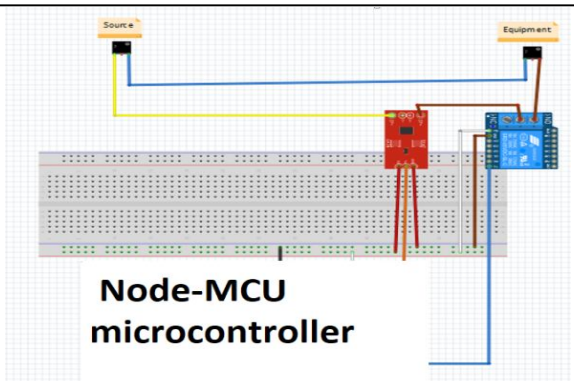


Figure 3: Hardware module.

The software module is responsible for changing the appliance state (ON/OFF) according to threshold value configured by household.
Node-MCU is a Lua interpreter understanding Lua scripts easily, and will be executed sequentially. Scripts will be sent to Node-MCU without getting transformed to binary[13]. The two previous algorithms will communicate the appliance power consumption to IoT platform through the IoT port.

3.3. IoT Platform LCCU Procedures

In the proposed architecture, the IoT platform is considered as an intermediate layer between user interface and appliance microcontroller board.Most of IoT platform such as Amazon, Microsoft and other provides set of APIs to third parties to enable integration with their platform. LCCU proposed set of procedures created on IoT platform to manage device's states and to create device's rules.These rules can be configured by household using mobile interface.According to these rules, IoT platform will take set of actions such as turn ON/OFF devices, send notifications to household and save data to IoT database. The following is an example of a simple rule:

When app_consumption greater than or equals to 100KWH →turn-OFF device and send notification to household.

3.4. Household Mobile Interface

LCCU provides mobile interface that enables household users to interact with the LCCU devices through IoT platform set of APIs. Using this interface, the power consumption threshold value for an appliance can be configured.One can receive appliance's data, charts that represent appliance's consumptions vs user preference consumption value.Also, user can receive notification from IoT platform.

IV. EVALUATION OF PROPOSED ARCHITECTURE

The Node-MCU controller shown in figure 4, has been configured to communicate with AWS IoT

platform through MQTT and CoAP protocols through secure communication channel based on 509x certificate downloaded from amazon IoT platform.Node-MCU is an open source platform equipped with Wi-Fi enabled ESP8266 chip[6][12].

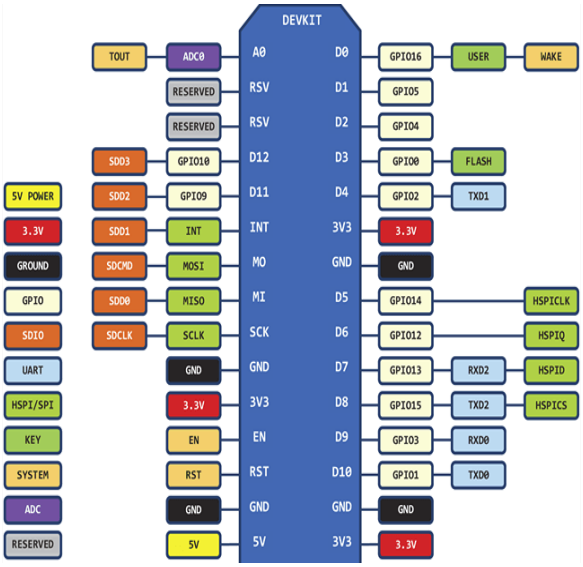


Figure 4: Node-MCU microcontroller

The AWS is the chosen IoT platform for this prototype due to its secured communication between LCCU device and the backend as shown in figure 5.

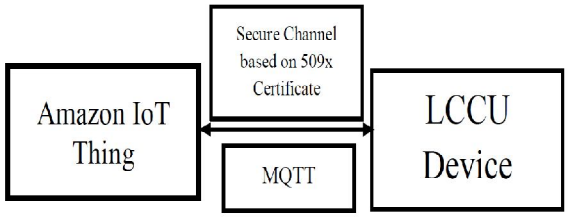


Figure 5: IoT to LCCU communication

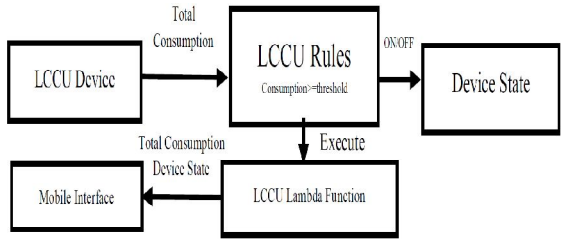


Figure 6: LCCU IoT platform

Figure 6 describes how the LCCU and IoT communicates and interacts together. LCCU device software module sends total consumption in KWH to AWS rule engine that in turn will execute the LCCU Lambda function, passing data from the MQTT message which triggered the rule. Data and device state can be sent to user mobile interface by LCCU rules.

Our prototype cost is $30 and estimated to drop to $10 for mass production. This cost is less than the available systems offered in the market which offers monitoring and/or controlling within short range via Wi-Fi or Bluetooth .

CONCLUSION AND FUTURE WORK

AnLCCU prototype has been proposed for monitoring and controlling single home appliance. The proposed system has proven to be cost affordable compared to conventional SMs, and convenient to accessed by users from any web enabled device. The estimated cost for our system is expected to be $10 if mass production was chosen which is much cheaper than other systems available in the market. The communication with the device is very secured with the MQTT and CoAP messaging protocols based on 509x certificate by Amazon IoT platform. More enhancement is undergoing to connect more appliances to get a better understanding of the total power consumption.

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