Design of IoT based Smart Energy device for Demand Side Management

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Acknowledgements

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Most importantly, we would like to thank our parents for putting their trust and faith in me, tolerating the distance and allowing us to choose our own we would like to thank our friends for their constant support.

Abstract

Our research is based on smart energy. A smart energy system is a cost-effective, sustainable and secure energy system. In this system renewable energy production, infrastructures and consumption are integrated. It is also coordinated through energy services, active users and enabling technologies. The smart energy system will be cost efficient and reliable. Our objective is to develop a system which can control electrical devices and collect data. We have to make a smart energy meter that can collect and analysis power consumption. In its later version it can have inter network between devices so we can control and observe everything from a single server room. By using cloud server we can involve our smartphone to make sure no energy is being wasted.

Chapter 1
Introduction

1.1 Internet of Things

The concept of Internet of things (IoT) was introduced by the growth of the widely used global network known as the internet along with the deployment of ubiquitous computing and mobiles in smart objects which brings new opportunities for the creation of innovative solutions to various aspects of life. The concept of Internet of things (IoT) creates a network of objects that can communicate, interact and cooperate together to reach a common goal [1]. IoT devices can enhance our daily lives, as each device stops acting as a single device and become part of an entire full connected system. This provides us with the resulting data to be analyzed for better decision making, tracking our businesses and monitoring our properties while we are far away from them [3]

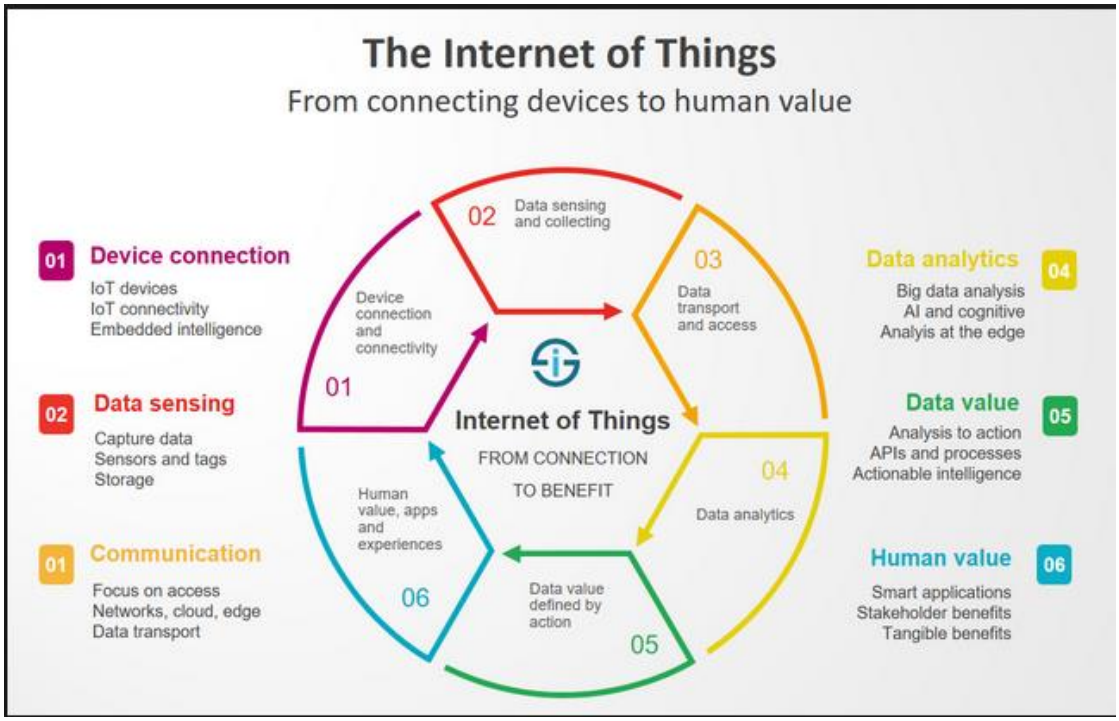

Figure 1. 1: Evolution of internet and internet of things

1.2 Internet of Things Applications

As the paradigm of IoT is growing, it is stepping into every aspect of our lives. This leads to an easier life through wider range of applications, such as electronic health care solutions [2] and Smart city concept. The concept of Smart city aims to making a better use of resources, increasing services quality offered to the citizens, and reducing costs of the public administrations [10]. Another application is home automation which is the main focus of this project.

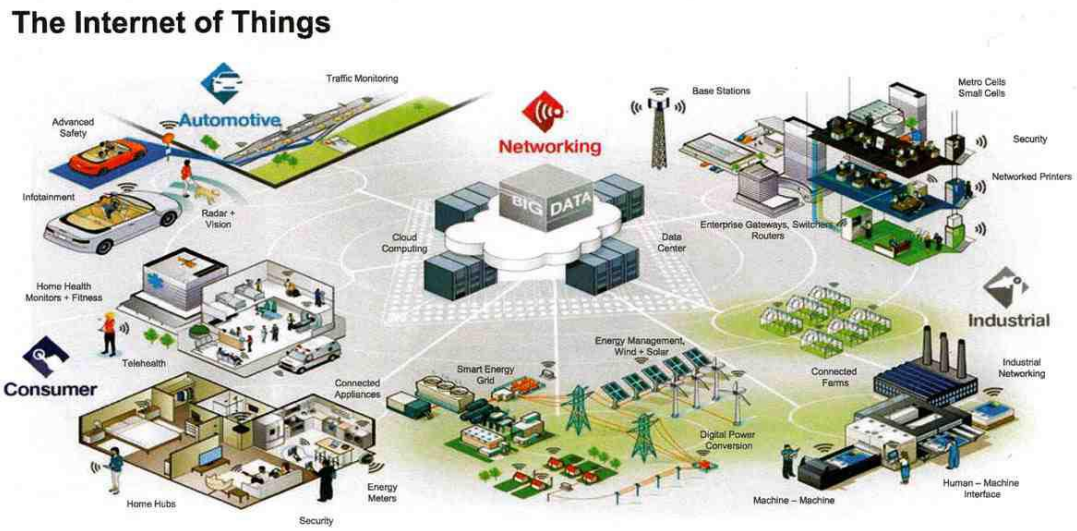

Figure 1. 2: Shows different applications of internet of things in all aspects of life

1.3 Aim and Objectives

Our objective is to develop a system which can control electrical devices and collect data. We have to make a smart energy meter that can collect and analysis power consumption. In its later version it can have inter network between devices so we can control and observe everything from a single server room. By using cloud server we can involve our smartphone to make sure no energy is being wasted.

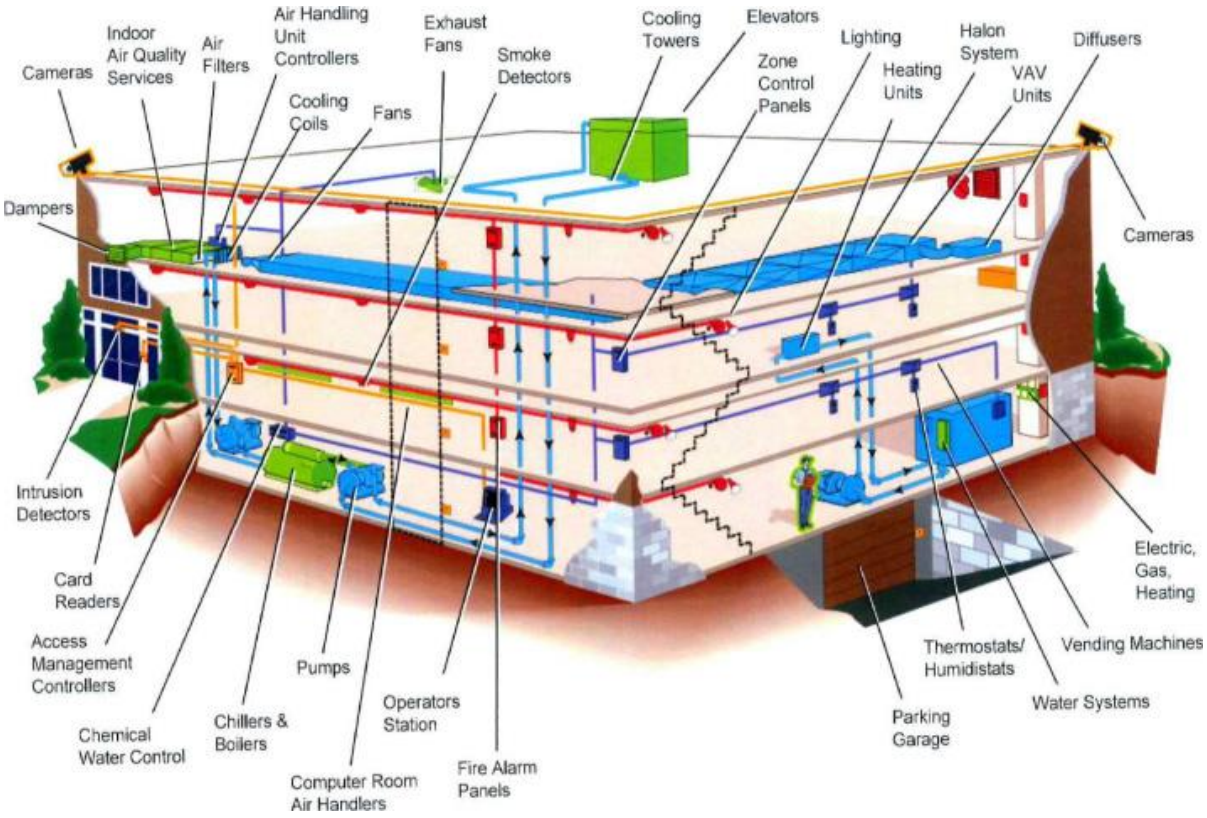

Figure 1. 3: Shows different use cases of IoT in Home/Industry

1.4 Motivation

The main motivation of this research work is to make the peoples life easy to save energy. Our smart energy meter will make the electricity billing process more transparent over using a prepaid meter. One can monitor the whole situation from the smartphone. With our device we can easily control our household, industry or office devices in a moment

During the past few years, internet was known as a big mass that we can acquire data from. Embedding mobile transceivers to everyday items and gadgets enabled new forms of bi-directional communication between people with other people, and people with things. That paradigm, known as Internet of Things, that was first introduced in 1998 by Kevin Ashton, has received recently more attention in the academia and industry [8], and this would add a new dimension to the world of Information and communication technology.

While that paradigm is growing and have high positive impact on many aspects of our lives, challenging issues arise, that should be considered and addressed. The central issues are guaranteeing security and privacy of users and their data. Another issue is fully achieving smartness of interconnected devices by enabling their interaction. Exchanging data and autonomous behavior is the key to achieving the latter [4]. IoT has different definitions from different perspectives, however, they all revolve around "things" generally, collecting, exchanging and communicating data with each other and with people through the "internet". IoT helps in decision making and automating almost everything around us. The smarter life IoT vision promises in the near future through various applications, made smart Energy Device actually possible, starting from basically monitoring different parts, to actually controlling them. Integration of IoT and Home or Industry, made it possible to monitor and control homes and industry from different parts of the world. Some examples of applications to this are: controlling and setting the desired temperature of the house before arriving home, turning on/off the lights of a room and setting its intensity, running washing machine while the person is at work, leakage or smoke detection and notification, monitoring home through surveillance camera or car inside the house while the person is away, or remote central locking, and many other applications.

Chapter 2
Background

IoT aims in creating a network between objects embedded with sensors, that can store, analyze, communicate and exchange data together over the internet. This leads to efficient industry, manufacturing, efficient energy management, resource management, accurate health care, smarter business decisions based on analyzed data, safer driving through smart cars that are able to communicate together, smart home automation and countless more applications.

As this project focuses on smart home automation through IoT, smart home concept should be understood first. Smart homes combines common devices, found in homes, to be able to control it. The technology originally was developed and used to control environmental systems, but recently, almost any electrical component can be included within the system [7].

The system designed for the home automation project presented in this paper needs a control unit, a computer, to be able to control the different electrical devices connected to it. For simplicity and capabilities, ESP 8266 has been chosen to be the control unit of this project 1. Data stream network is the infrastructure and network that connects devices from anywhere in the world, allowing developers to build real-time applications in a secure and reliable manner.

Cross-platform software is a software developed to be run on multiple and different platforms such as web, iOS or Android. Ionic, is an open source SDK for developing cross- platform applications using HTML, CSS and JS components. It was used in developing the mobile application used in testing the developed approach in this project.

Chapter 3
Methodology

3.1 System Architecture and Approach

The first thing that had to be thought about after choosing this topic was the system architecture. How will the appliances and devices communicate with a web/mobile application, receive commands and send their status? Should it be a server client protocol, in which there is a direct connection between the devices and the application used by the user? How will a direct connection be established over the internet? Or should the client and server communicate through a medium channel that the messages should be passed on before reaching the client or the server? These questions had led to exploring different approaches and services. ESP 8266 was chosen as the main control unit, to connect different sensors and devices together and to the internet. The ESP 8266 is a chip little development board, that has GPIO pins and capable of being programmed, so it was chosen for its simplicity, capabilities and low price.

The next challenge, after finding a way to connect different devices together and to the internet was actually controlling them over the internet through a web/mobile application built using Ionic Framework. Different ways and services were explored including setting-up port forwarding on the router. Setting-up port forwarding will change the configuration of the router and expose one port of the private Local Area Network (LAN) to the public, which is considered a security vulnerability that has to be managed carefully.
Some of the services that were explored and considered to allow the communication of the web/mobile application with the ESP 8266 connecting different devices are Weaved, Pusher and AWS Mobile Hub. However, the need of real-time interaction it was chosen as the most adequate solution.

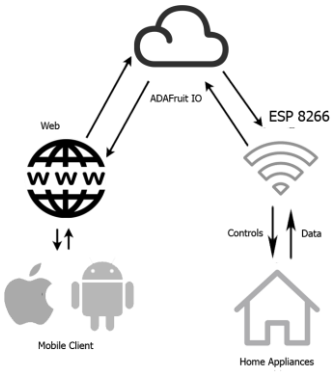

Figure 3. 1: Illustrates the system architecture used in this home automation project.

3.2 Simulation

An essential part of the project was simulation, testing and analyzing results. Proteus and Fritzing was used in designing different parts of the device.

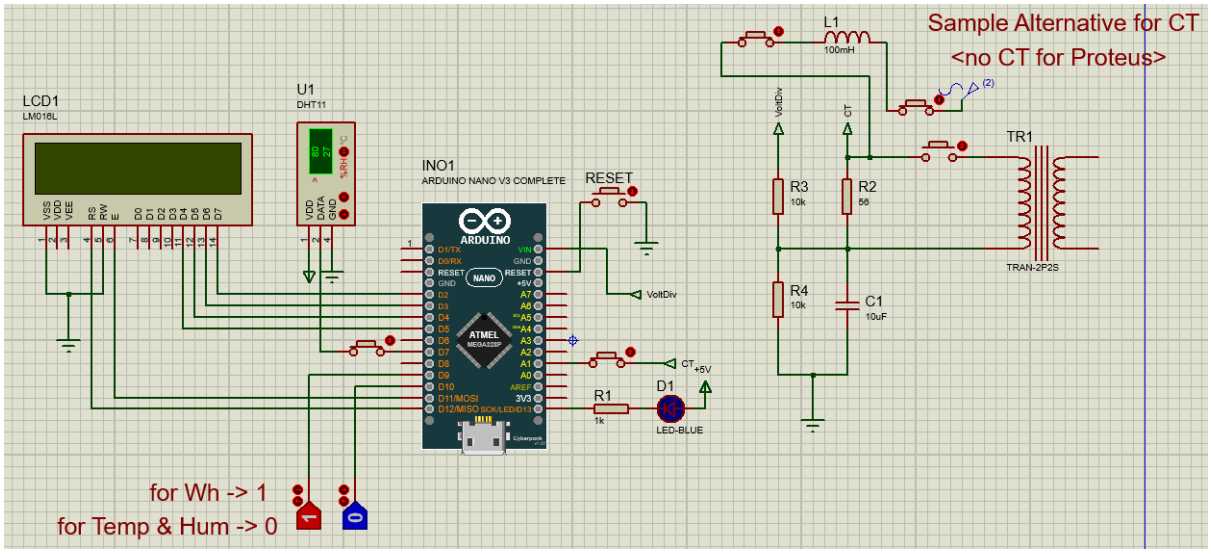

Figure 3. 2: Proteus Simulation with Arduino

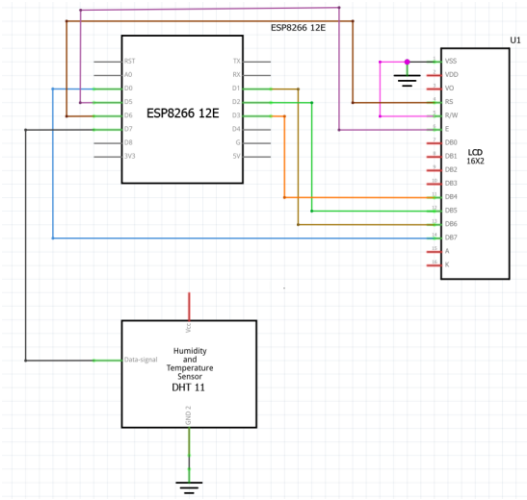

Figure 3. 3: Circuit with ESP 8266 in Fritzing

3.3 Technical Solution

3.3.1 Components

The components used for energy meter are as follows:

- ESP8266
- DHT11
- Current Transformer (non-invasive clamp type)
- LCD 16×2
- Multiplexer (for Plug-n-Play)
- MQTT & IO

3.3.2 Using ESP8266 for IoT

ESP8266 12e is a great development board with built in microprocessor and Wi-Fi chip. It is a low cost one & and very small to accommodate. It has PWM, SPI, Digital I/O, one ADC etc. It has different boot modes [11].

ESP-12E is designed and developed by Shenzhen Doctors of Intelligence & Technology (SZDOIT) based on the Ultra-low power consumption UART-Wi-Fi ESP8266, which is specially for mobile devices and

application of IoT (Internet of Things). Now, ESP-12E is widely applied to internet, communication in local area, intelligent home, industrial control, handed-devices, and etc.

ESP-12E DevKit is used the design of on-board antenna and encapsulated by 2.54 direct insertion. It is very convenient to debug and install device.

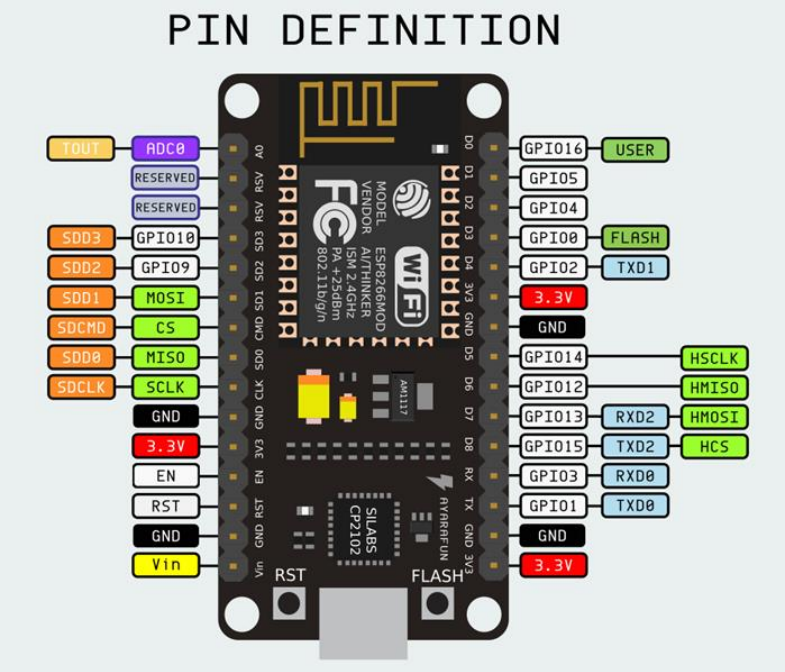

Figure 3. 4: Pin configuration of ESP 8266

In ESP-12E DevKit, Hardware API operation is encapsulated by Lua language, which can avoid the hardware difficulty for sorfware engineers, and then can speed the development of products.

3.3.3 DHT11 for temperature and Humidity

This DHT11 Temperature and Humidity Sensor features a calibrated digital signal output with the temperature and humidity sensor complex. Its technology ensures the high reliability and excellent long-term stability. A high-performance 8-bit microcontroller is connected. This sensor includes a resistive element and a sense of wet NTC temperature measuring devices. It has excellent quality, fast response, anti-interference ability and high cost performance advantages [12].

Each DHT11 sensors features that extremely accurate calibration of humidity calibration chamber. The calibration coefficients stored in the OTP program memory, internal sensors detect signals in the process, and we should call these calibration coefficients. The single-wire serial interface system is integrated to become quick and easy. Small size, low power, signal transmission distance up to 20 meters, makes it a variety of applications and even the most demanding applications. The product is 4-pin single row pin package. Convenient connection, special packages can be provided according to users need.

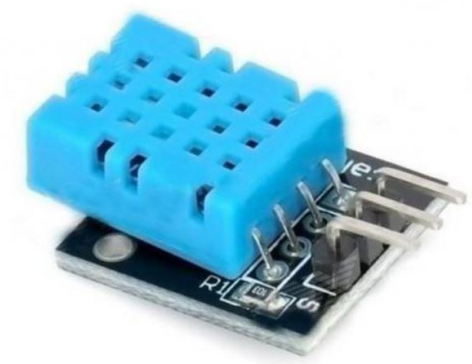

Figure 3. 5: DHT11 Sensor

3.3.4 Current Transformer (non-invasive clamp type)

This non-invasive current sensor clamped around the supply line can measure a load up to 30 Amps, and allow you to calculate how much current pass through it. It can be useful for building your own energy monitor or for building an over-current protection device for an AC load. Current transformers (CTs) are sensors that are used for measuring alternating current. They are particularly useful for measuring whole building electricity consumption (or generation for that matter) [13].

The split core type such as the CT in the picture above, is particularly suitable for DIY use it can be clipped straight on to either the live or neutral wire coming into the building without having to do any high voltage electrical work.

Figure 3. 6: Current Sensor

3.3.5 MQTT & Adafruit IO

MQTT means Message Queuing Telemetry Transport in full. MQTT is a great protocol. It's extremely simple, and light-weight. Connecting to a server only takes about 80 bytes. You stay connected the entire time, every data 'publication' (push data from device to server) and data 'subscription' (push data from server to device) is about 20 bytes. Both occur near instantaneously [14].

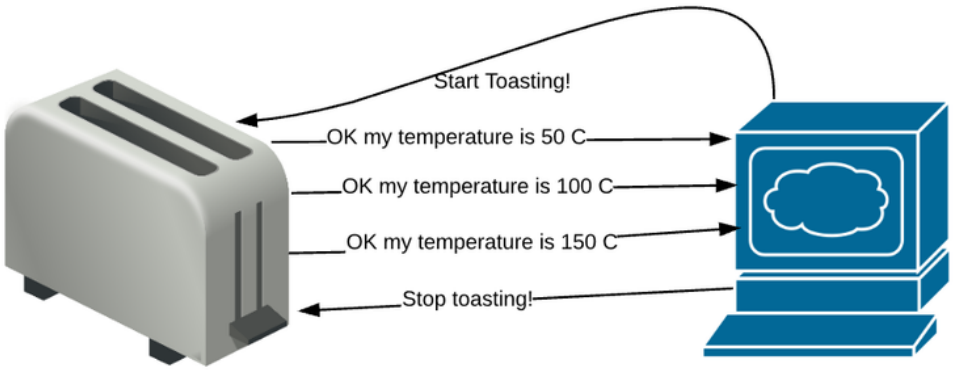

Figure 3. 7: MQTT broker example

Thus we have no 'build up and tear down' overhead, and we can stream data in and out of multiple 'topics' quickly and easily. MQTT can run on top of any kind of network, whether it be a mesh network, TCP/IP, Bluetooth, etc. Since we'll be connecting to adafruit.io, the MQTT style we'll be discussing runs on top of a TCP/IP connection.

Cellular and Wi-Fi and Ethernet all connect pretty easily to TCP/IP so that makes it easy to connect directly to adafruit.io

If you are using Bluetooth, XBee, Bluetooth LE, or another non-Internet-connected protocol & device, you will need a gateway! For example, the Adafruit Bluefruit Connect app has a BLE adafruit.io gateway for passing data back and forth.

Chapter 4
Use Cases and Results

Both, the ESP8266 and the mobile application, are senders and receivers of data. We use Arduino IDE for code. Accordingly, multiple use cases were implemented and studied for result analysis.

4.1 Use Cases

4.1.1 Energy Usage Monitoring

Our device can measure voltage and current. So we can use it as an energy meter. We can monitor how much electrical energy has been consumed. Our device can detect threshold value of usage and stop it accordingly. We can monitor home appliance using their energy consumption.

4.1.2 Humidity and Temperature

We can also monitor humidity and temperature using our device. Thus we can control our air conditioner and other related things by means of temperature. We need a simple modification to take over all the appliance in the house.

4.2 Results

We have the software part only and we have got satisfactory results.

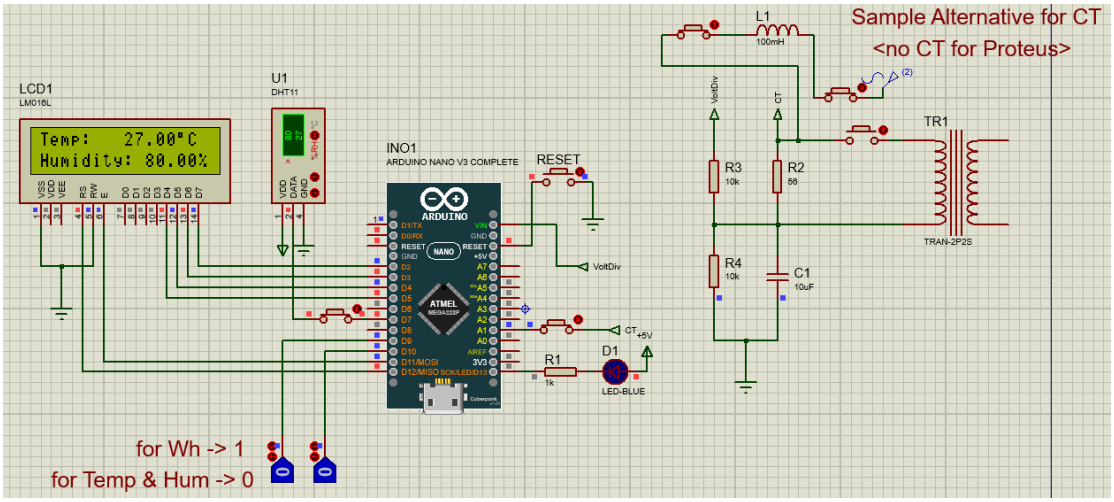

Figure 4. 1: Simulation Running in Proteus for humidity and temperature

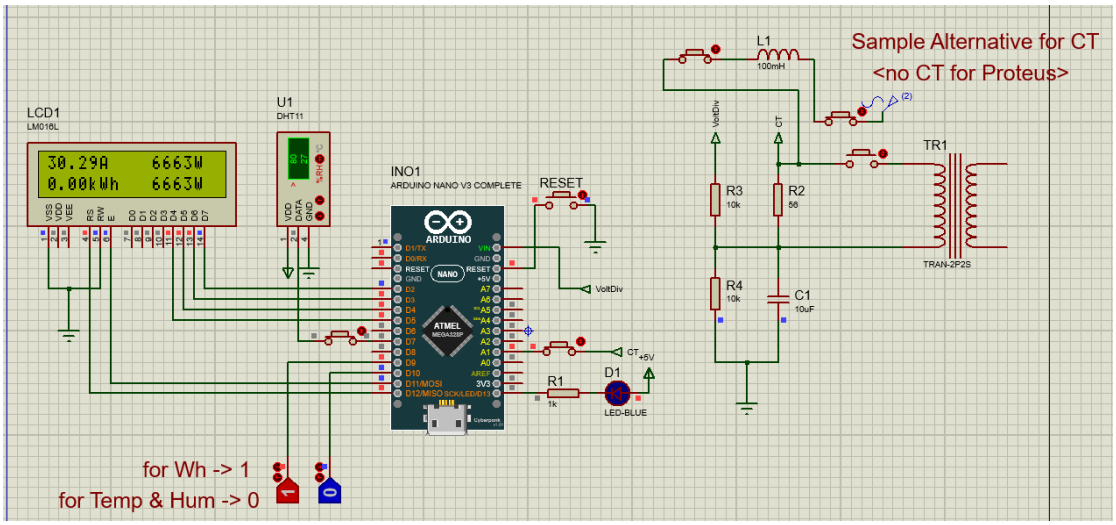

Figure 4. 2: Simulation Running in Proteus for CT

Chapter 5

Conclusion

Our energy monitoring system is sustainable in a sense that our research will provide a device in a low cost which will save out daily electricity bill. Our smart energy meter shows energy usage and give remote control. This will make the electricity billing process more transparent over using a prepaid meter. The existing devices are expensive and not available in our country. So if anyone wants to apply our kind of device, they have to use our device.

It provides easier and economic living for every person. In this project, an approach for developing an IoT software-based smart energy monitoring system was implemented. It focuses on energy management using some of the recent available technologies. The technologies used in implementing this project are: ESP 8266 was used as the main control unit of the project, in which different devices and sensors were connected to it; MQTT, broker server, was used as the way of bi-directional connection between the two ESP 8266 from an end, and the mobile application from the other end.

Chapter 6
Future Work

IoT is having tremendous attention recently and its various applications are growing, changing the way we live and work. This project's main focus was on monitoring energy usage, which is a small part of what can be automated and controlled inside a smart home. Future work focus would be working on actual AC devices to implement what was simulated.

We are using Adafruit IO MQTT server. We may have our own gateway which should be done by other groups. We will have a plug n play basis extensions. We can use some other clients like LoRa. As there are various appliances that can be controlled and automated while being away from home, the same approach used in implementing this project will be used to enable control over various appliances before reaching home, saving time and effort; Such application examples can be controlling stoves and microwaves, creating carbon footprint autonomously depending on the visitor respiration and many others that would combine IoT with smart appliances autonomy.

Appendix

List of Figures

1 http://iottech.dk/wp-content/uploads/2014/10/evolution-of-iot.png
2 http://frikiyo.es/wp-content/uploads/2016/04/internet-de-las-cosas.jpg
3 https://s-media-cache-ak0.pinimg.com/736x/8d/12/ac/8d12ac256d6fc5beebba14138423d543.jpg
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List of Acronyms

IoT	Internet of things
Wi-Fi	Wireless Fidelity
LoRa	Long Range
MQTT	Message Queuing Telemetry Transport
IO	Input Output
CT	Current Transformer