Coordinated Application for Saving, Time, Energy and Money in a Smart-Home

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Abstract—*In this paper, we present a system for coordinating applications, saving, time, energy and money (CASTEM) in a smart-home (SH). The system aims to address the issues of energy optimization, convenience, automation, security and safety, and entertainment in a SH. To demonstrate the application of CASTEM, a prototype has been developed which consist of a gateway, SH model, internet of things (IoT) and the preliminary results are presented. It is expected that the use of CASTEM will enhance the standard of living conditions within a SH, reduce energy wastage, provide real-time analysis and help save money.*

Keyword— Automation; energy optimization; Internet of Things (IoT); smart home

1 INTRODUCTION

The emergence of internet of things (IoT), ubiquitous connective, the increase in use of smart mobile devices, have paved the way for adoption of smart home (SH) in recent time. This is motivated by the increase of an ageing population, the need to enhance the quality of life within the home, the need to reduce cost, and need to promote safety within the home among many others. The concept of SH can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond.
There are several use cases of SH that have been discussed in the literature. Examples of such use cases include the following: monitoring of daily activities within the home [1], energy conservation and optimization [2], [3], health care [1], [4], security management [5], and home automation [6]. Unlike the existing work which focuses on different applications in a smart home, in this paper, we propose a system for coordinating applications, savings, time, energy and money (CASTEM). The system is designed to provide convenience, coordinate the different applications in a SH, optimize energy consumption, promote security and safety of the SH and ultimately help save money. In this paper, the term smart-home also refers to a smart building. The rest of this paper is structured as follows. In Section 2, the key features of CASTEM are presented. Section 3 covers the methodology and setup of CASTEM. Section 4 discusses the preliminary results and Section 5 concludes the paper.

2 KEY FEATURES OF CASTEM

In this section, we discuss the key features that CASTEM intends to address in a SH. They include coordinating applications, savings, time, energy and money.

2.1 Coordinating Applications

Thanks to the introduction of smart devices like the Google home and Amazon echo [7], which are voice activated for interaction with services through intelligent personal assistants. Others include smart electrical appliances such smart kettle, rice cooker, purifier, LED bulbs, lightings and locks. These smart devices can be configured using smart portable devices via Wi-Fi, Bluetooth or other forms of communication technologies. Most of these smart devices are limited to home automation via preconfigured settings or scheduling without considering energy analysis and operational efficiency. To this end, CASTEM aims to enable coordinated application of smart devices which takes into consideration operational efficiency, energy optimization, activities and real-time analysis within a SH. This can be achieved by using scheduling algorithm, use of machine learning to learn the pattern of operation and activities within the SH.

2.2 Savings

The CASTEM aims to enable savings within a SH by providing early notification in emergency situations such as fire hazard, gas leakages, and electrical overloads. Such notification can activate safety modes within the SH. In addition, the ability to reduce energy wastages by using smart sensors to detect and control electrical appliance will lead to a reduction of electricity bills. These features will enable saving of lives, money and property within the SH. Furthermore, homeowners can specify the amount of energy bill to be used within a period and the smart appliances within the home can be optimized based on environmental parameters, critical task, peak and off-peak charges.

2.3 Time

Time remains an essential part of our lives. There several ways SH can help save our time such as providing control of all appliances within the home and remotely from our smart devices. Appliances can be pre-scheduling and remotely automated without the need to operate them directly.

2.4 Money

The current challenge of adopting SH is the initial cost of installation, especially in existing buildings. The ability to provide a return on investment (ROI) over a short period can be a motivating factor for existing homes to adopt the SH technology. Although it is expected that the cost of setting up a SH over time will get cheaper, CASTEM is expected to deliver ROI within a very short time for users. CASTEM algorithms and optimization techniques take into consideration several factors such as environmental conditions, peak and off-peak tariff, human activity within the home to help drive energy bills down while maintaining convenience. In addition, users can specify the amount of energy monthly consumption and cost to be used

2.5 Energy

The increase in connected devices will lead to increase in power consumption within the homes. Although, manufacturers are making appliances which are more power efficient, however, electricity tariffs are still on the increase. Hence, the need to reduce wastages by using different techniques such as scheduling of appliance, on and off lighting using context awareness techniques, control of heating ventilation and air conditioning (HVAC) with environmental factors such as temperature, humidity and intensity of light.

3 METHODOLOGY

The CASTEM consists of four main components which are smart-home model with sensors (rain, temperature, current, motion, gas, humidity, magnetic, light) and actuators (servo motor, buzzer) IoT cloud (Thingspeak), gateway (Raspberry Pi-3) and apps (mobile apps and desktop apps). Figure 1.0 illustrates the system model.

A prototype of the CASTEM was developed using raspberry Pi-3 as the gateway, Thingspeak as IoT cloud, and mobile app was developed using Android studio while the desktop app was developed using MATLAB 2015a. There are four phases used to achieve the aim of CASTEM. They are monitoring, analysis, optimization and prediction phases. The phases are discussed as follows.

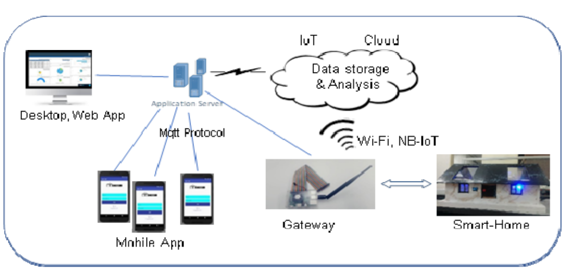


Figure 1.0: System model for CASTEM

3.1 Analysis

There are several analyses that can be carried out in the SH. These include energy usage analysis, efficiency analysis, cost analysis, operational analysis, and correlational analysis. For instance, using the Algorithm 1, the energy usage analysis can be carried out by calculating the energy consumption per time in kWh.

Algorithm 1 Energy Calculation (KwH)

```
Initialize StartTime = 0, EndTime = CurrentTime, SamplingTime = 1
  ▷ CurrentTime is a fucntion, giving sampling time is 1s
while True do
    StarTime = CurrentTime
    if StartTime − EndTime ≥ SamplingTime then
        for each x ∈ M do                          ▷ M is total measured appliance
            watt = watt + AppliancePower[x]
        end for
        TotalWatt = TotalWatt + watt                ▷ Cumulative power
        TotalKwh = TotalWatt ∗ samplingTime/1000/3600     ▷ convert
  from w to Kwh
        watt = 0                                    ▷ Reset watt
        EndTime = CurrentTime                       ▷ Overwrite EndTime
    end if
end while
```

3.2 Monitoring

In the SH, real-time monitoring can be carried out and logged to the IoT cloud using sensor nodes. The Algorithm for the monitoring phase is described in Algorithm 2.

Algorithm 2 Monitoring Phase

```
Initialize Internet Connection
Initialize Sensor Node
Initialize StartTime = 0, EndTime = CurrentTime, SendingInterval =
  30   ▷ CurrentTime is a fucntion, giving interval time of sending data to
  cloud is 30s
while True do
    StarTime = CurrentTime
    if No Internet Connection then
        Reconnect to Internet
    else if StartTime − EndTime ≥ SendingInterval then
        Read Sensor Node
        Process data into packet
        Send data to cloud
        Save data in local server
        EndTime = CurrentTime                 ▷ Overwrite EndTime
    end if
end while
```

3.3 Optimization

The optimization phase enables home owners to specify the amount of energy to be consumed for the month. There are different modes that can also be activated such as super saving mode, economy mode and normal mode. The optimization of energy consumption based on maximum cap specified by the home user can be expressed as follows.

$$\min_{X_i} \sum_{i=0}^{T} y_i \quad \text{s.t.} \quad \sum_{i=0}^{T} y_i \le \frac{\gamma}{T} \qquad (1)$$

where y_i and X_i is the total cost and on/off, respectively in time slot i and denoted as $y_i = [\overline{C} \square \overline{U} \square \overline{X}] \cdot \overline{R}$.

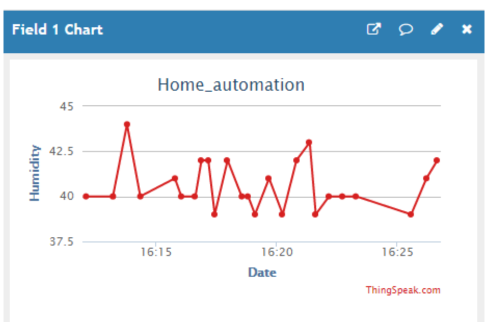
$\overline{C},\overline{U},\overline{X},\overline{R}=[1\times M]$ and represents critical tasks (must be switched on), user controlled (forced on), binary on/off and rate of each appliance, respectively. The $T,\frac{\gamma}{T}$ are the total sampling time of usage and maximum cost of energy to be consumed per month in time T.

3.4 Prediction

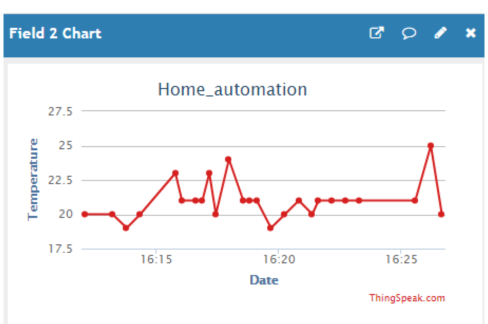
There are different types of machine learning methods that can be used to predict the amount of power to be consumed and to recognize the activities within the SH. Examples of such prediction models are Bayes belief networks, artificial neural network, sequential minimal optimization and logitBoost [8]. We shall explore the use of Bayes belief networks in our future work, where each group of data collected will be modelled and classified into different observation models. The state models of the devices will be compared with the measured data and based on the comparison, a self-optimizing correction factor can be implemented while providing a prediction of the behavior of each device. The prediction will provide information of possible device behavior and actions that can be taken to achieve the features of CASTEM.

4 RESULTS

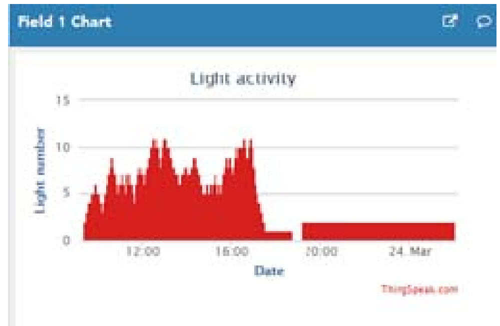
In this section, we show the preliminary results of real-time monitoring of the environmental parameters such as; temperature and humidity, operation of lighting points and air condition, power consumption and accumulated power consumption for the SH model.



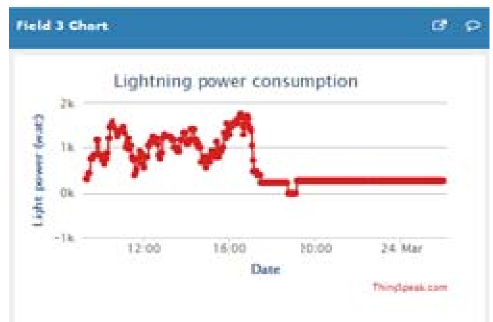
(a)



(b)



(c)



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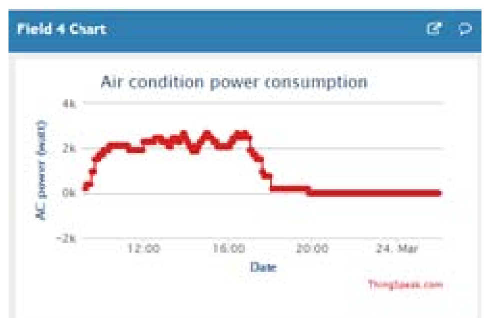
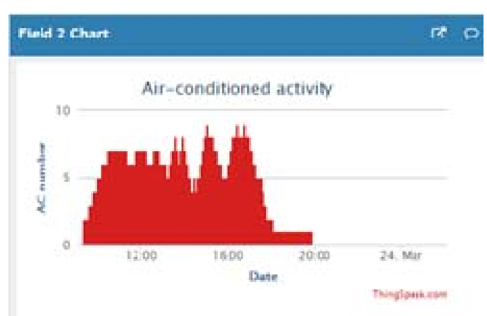


(e)



(f)

(g)

Figure 2.0: Real time monitoring of SH using Thingspeak IoT platform (a) Humidity (b) Temperature °C (c) air condition activities (d) operation of all the lightings (e) power consumption for lights, (f) power consumption for air condition, and (g) accumulated power consumption

The preliminary results in Figure 2, illustrates the monitoring activities and power usage. The results of the data analysis are not included in this paper due to limited space. From Figure 2 (c) and (d) shows that the number of lighting points and air-condition active after 19.00 hours reduces. This is because of less activities after 19.00 hours. This results to a corresponding decrease in energy consumption as shown in Figure 2 (e) and (f), respectively.

5 CONCLUSION

In this paper, a system for coordinating applications, saving, time, energy and money (CASTEM) in a smart home has been presented. It incorporates IoT and data analysis to enhance the living standard, reduce wastages, optimize energy consumption within a smart home. The system incorporates a gateway, IoT cloud and Wi-Fi communication technology. Future works intend to implement SH in wireless communication building using the narrow-band IoT (NB-IoT) communication technology, provide analyses and test the optimization techniques.

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