WTAS: A Cost-Effective Smart Tinkering Lab Automation System

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Abstract— In this research article, we proposed an IoT enabled, cost effective smart tinkering lab automation system named "Wireless Tinkering Lab Automation System" (WTAS). The system is deployed in the Tinkering lab of the "The NorthCap University" Gurugram (Haryana). WTAS uses amazon alexa echo (voice control), smart sensing, scheduling appliances for specific routines, biometric digital door lock and lab utilization analysis to control lab functions and features automatically through the internet. This system is designed to be low cost, time saving, convenient and energy saving allowing smart control of all electrical appliances, along with ensuring ease of door access permissions and generating lab resource utilization analysis for better decision making. All the functionalities are controlled and accessed by the administrator via android application thereby aiming to fully automate the work of the lab technicians.

Keywords - component: Automation; Tinkering; Smart Lab; Amazon Echo; Alexa; Internet of Things (IoT; Security System; Biometric; Digital Door Access; Analysis; Android; PIR motion sensor

I. INTRODUCTION

In today's world, with the rapid growth in automation technology, manual systems are gradually being replaced by smart frameworks, reducing the involvement of humans and improving user experiences [1]. Different appliances of a smart home/office reach out each other to an extent of controlling, monitoring and improvising the accessibility from anywhere around the globe with the help of an interface which is provided by the Internet of Things (IoT) [2]. IoT can be defined as multiple devices/objects connected over a network interacting with each other. The 'thing' in IoT could be a person with a heart monitor or an automobile with built-in-sensors which has the function to transfer data without any human intervention over the web. Figure 1 shows how home automation has advanced from the invention of the first smart device ECHO IV (1966-1967) to the time when smart homes began to see popularity in early 2000's [3-4]. Better results could be driven in the companies to improve performance through IoT based analytics and security. Organizations particularly working in the sector of utilities, oil and gas, insurance, manufacturing, transportation, infrastructure and retail sectors can seek the advantages of IoT by being decisive and being able to analyse the data more efficiently. The IoT market was valued at around $31,500 million in 2016 and it is expected to reach $ 158,140 million in 2024. The global market is expected to grow at a rate of 23% between 2017 and 2024.

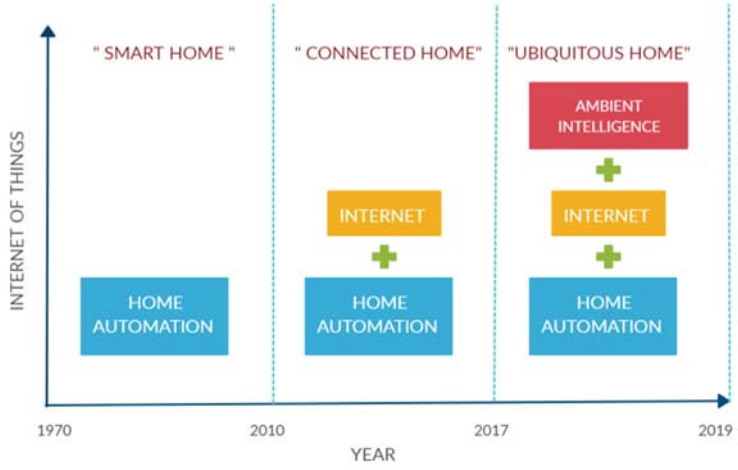

Figure 1. Evolution of Home Automation from 1970 – 2019

II. LITERATURE SURVEY

An automation system was proposed by Harshada Rajput in May 2018, which helps control electrical devices using voice commands over an android application using Wi-Fi communication between android device and raspberry pi. Their main aim was to make life easier, hence their system is mobile-based providing a user-friendly interface [5]. Home automation system with additional security features, with network connections through Wi-Fi was suggested by M. Ummay Hagera in 2018. The system includes a temperature sensor, fingerprint sensor, motion sensor, fire sensor, door status, and a camera. With the help of these sensors, the system has the ability to control and monitor many different physical parameters in the house [6].

The prime objective of Kalyan Kumar Jena's work published in 2019 was to automatically achieve some of the activities which we perform frequently in our daily routine to acquire comfort, freedom and security. Their system mainly focuses on three functionalities - Smart house system, fire security and burglar security system. The system has mainly three operating parts - Automation, Remote mode, Security [7]. Shivam Parashar in 2018 proposed a Home Automation System where users can control their home appliances by means of desktop/android application. In their system, voice alerts are sent to the owner, if any sort of human movement or emergencies like fire or other condition is sensed in the house and raises an alarm upon user's discretion. The user can control appliances through web app like opening gates, switching on tv etc. along with checking appliance history [8].

Advance IOT Based Home Automation was presented by Subhankar Chattoraj. Their main objective was security from unauthorized entry. In this paper they suggested a fingerprint recognition biometric system which provides complete security. In comparison to other security solutions like RFID they have found this method more secure. If the user's fingerprint has a positive match the door will open otherwise the GSM module will get triggered and the registered user gets a message and the buzzer goes off to alert security [9]. R. Sugantha Lakshmi proposed a system to monitor different parameters range which will increase the comfort of the users. They used the EmonCMS platform for collecting data and controlling devices. The sensing of various parameters is done using the NodeMCU-ESP8266 microcontroller, which allows real-time data sensing, processing and uses EmonCMS cloud [10]. Ravi Wankhade suggested a Home Automation System Based on IOT using Cellular Devices developed the system using Arduino and ESP8266 network module in the year 2019. Commands for controlling appliances can be sent through a mobile application via the internet [11].

The WTAS model proposed in this paper provides a way to control all electrical appliances of the lab through voice control, smart sensing [12-13] and android app using ESP8266 Wi-Fi module [14] as a communication protocol between Arduino UNO [15] and Google Firebase Real-time database [16]. Scheduling device routine functionality is also provided to set routine for specific devices. A biometric digital door lock [17] is installed on the main door of the lab providing security and access control thereby eliminating extra individual in-charge. Users can access the lab via biometric system which matches the input with the firebase records and opens the door if a match is found. Non-registered new visitors can access the lab by entering their details (name, purpose) on the camera equipped touch screen panel provided. Further the user details and photograph is sent on the admin's phone for access permission, the admin can unlock the door via the android app. The biometric punch- in/out database is further analysed for optimized utilization of technicians according to the number of students, their peak time and department. Also, sensor data is used to analyse appliances utilization.

III. PROPOSED WORK

The proposed WTAS model is a smart IoT enabled tinkering lab automation system providing five major functionalities within the context of lab usage. The general layout of the proposed model deployed in the tinkering lab of The NorthCap University is shown in Figure 2.

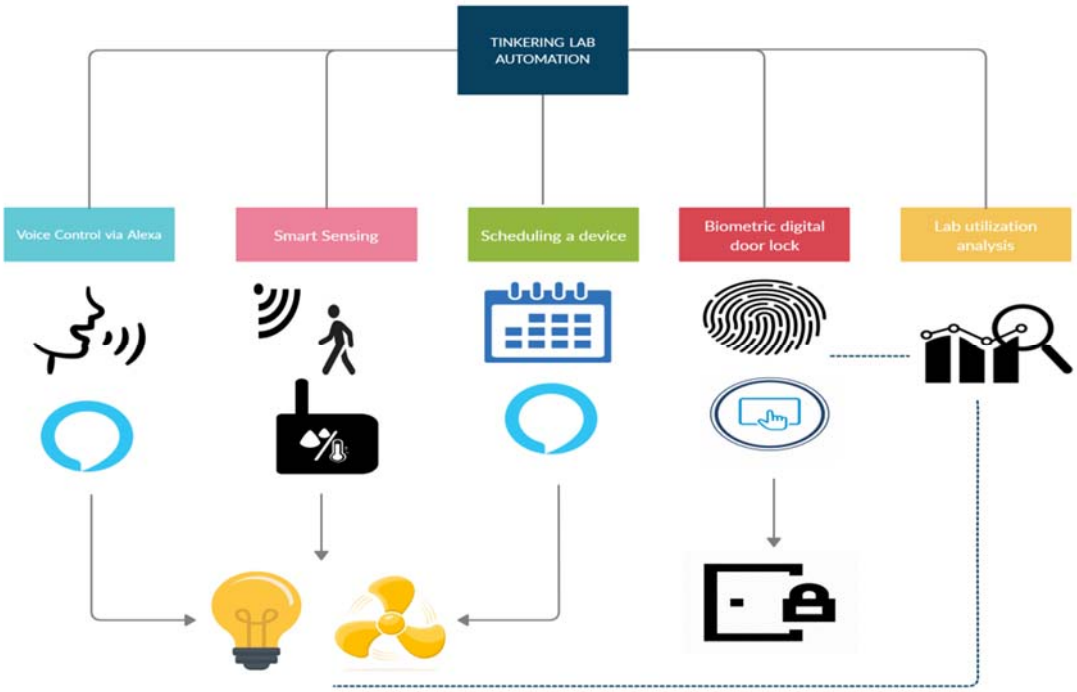

Figure 2. General Layout of five major functionalities in proposed WTAS model

Fig. 3 shows the internal and external setup of components in the tinkering lab in 2-D view. Biometric look and camera has been deployed at the entrance of the lab to facilitate lab access without lab attendant and to track the students, visitors from each department so as to find out the lab utilization. Lab utilization is important to check for proper and efficient utilization of lab resources.

Discussed below is the brief working of these functionalities:

- **Voice Control using Amazon Echo** – For smart control of devices we are using ESP8266 Wi-Fi module and UNO by which we will be able to control all electrical lights, fans by means of a voice-controlled system enabled through Alexa echo.
- **Smart Sensing** – Motion sensors and thermostat are used to detect the human presence and motion inside the lab. If someone enters the lab, then the lights and fans of appropriate location will get switched on.
- **Scheduling Appliances for specified routine** – Many tasks require to be done at specific time intervals, these routines can be fully automated by scheduling such activities.
- **Biometric Digital Door Lock** – The lab is equipped with a fully automated biometric door lock, which can be unlocked by any registered user and via android application where the Super Admin grants permission. The biometric system records the punch IN and OUT time of students and uses the data for utilization analysis & visualization.
- **Lab utilization analysis** – Lab utilization analysis is carried from biometric data and appliance utilization, these analyses help us use resources better and in an efficient manner and save time.

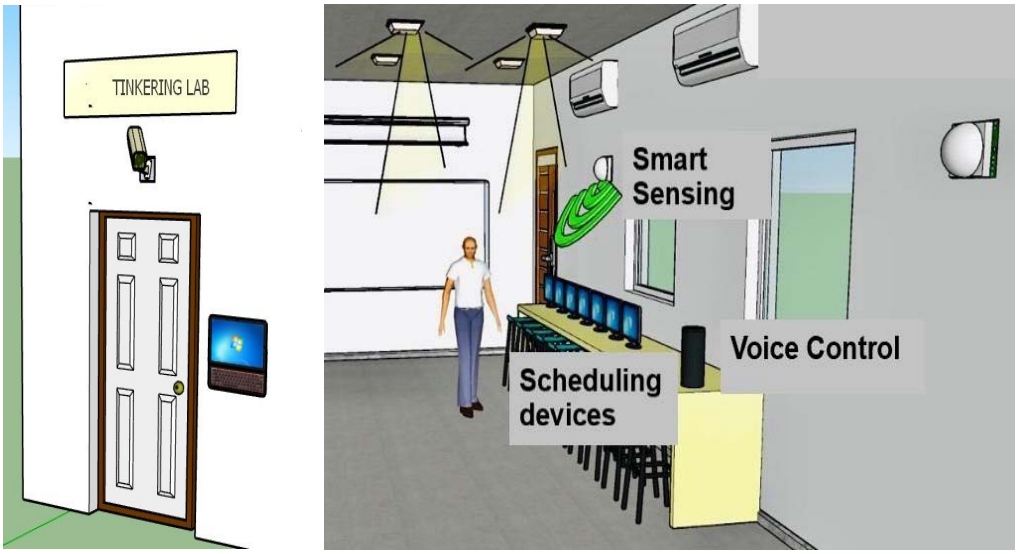

Figure 3. A 2-D view of internal functionality of Proposed Tinkering lab automation model (WTAS)

The following subsections present the detailed working of various services provided by the proposed WTAS model for tinkering lab:

Voice Control using Amazon Echo

Custom Alexa skill to control appliances is evoked by the command "Control lights". Alexa intents were coded specifically LeftLightOn, RightLightOn, CenterFanOff and so forth. Specific amazon lambda functions distinguishes the intent called by the client through alexa and calls the particular intent work appropriately if match found. The firebase (Cloud database) is updated with value 0 (OFF) or 1 (ON) and the values are sent to the Arduino via Wi-Fi module and relay then controls the electrical devices. Fig. 4 shows how a voice command is recognized by alexa and the flow of action via Wi-Fi module/arduino. Fig. 5 shows an alexa command to switch on the left light of the lab. These appliances can also be controlled via an android application. Figure 6a. shows the different modes available to control the devices. We can switch between manual mode and smart mode. Figure 6b. shows the control options via manual mode.

Figure 4. Sequence of events invoked by proposed Voice Control Automation

The following code shows the Amazon AWS lambda function for the intent of the LeftLightOn, hence sending "on" command to firebase and sending positive reply via Alexa.

```
handle(handlerInput) {
    const request = handlerInput.requestEnvelope.request;
    const
responseBuilder = handlerInput.responseBuilder;
    let
sessionAttributes = handlerInput.attributesManager.getSessionAttributes();
    var
req = https.request(options, function (res) {
    var
chunks = [];
```

```
        res.on("data",
function (chunk) {
          chunks.push(chunk);
        });

        res.on("end",
function () {
        var
body = Buffer.concat(chunks);
        console.log(body.toString());
        });
       });

       req.write("{\"LeftLight\":1}");
       req.end();
       let
say = 'Switching on the left light. ';
```

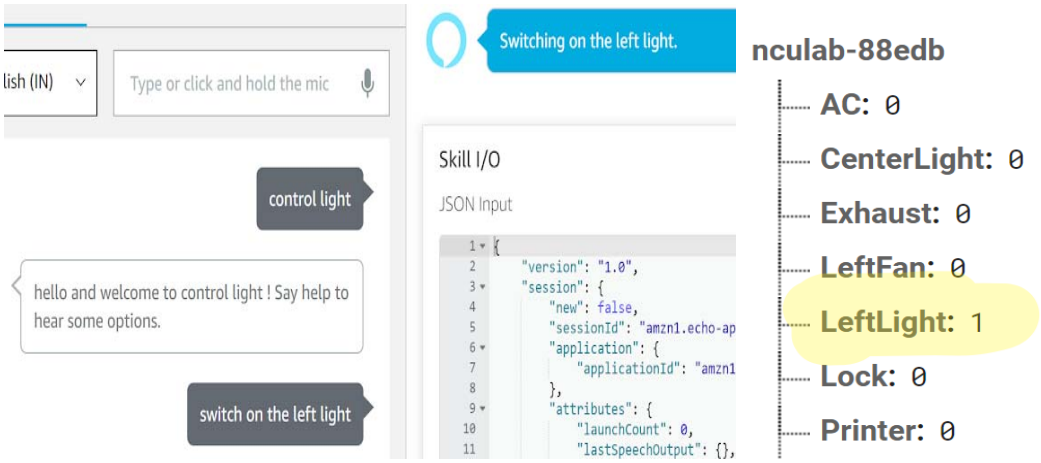

Figure 5. Alexa command for controlling appliances.

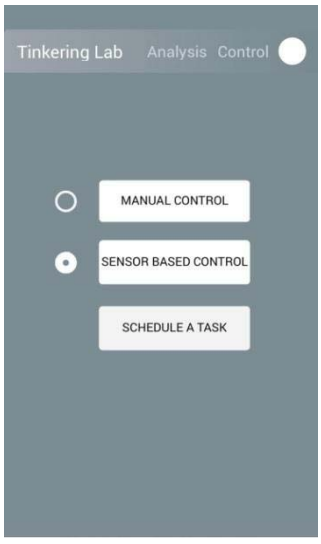

Figure 6a. Modes available in WTAS.

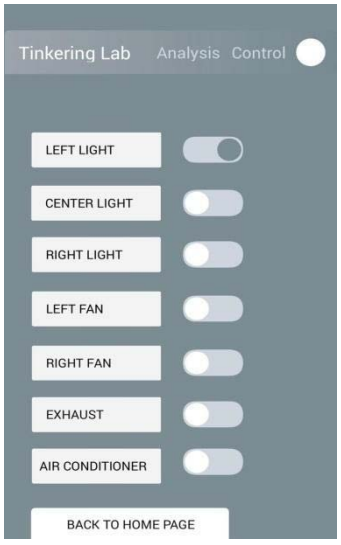

Figure 6b. Control buttons for appliances.

Smart Sensing

The Lab automation system has the capability to control the temperature and humidity, and Motion detection. PIR sensor is used for automatic control but PIR sensor does not work properly with static bodies, hence a small rotating disk is added in front of it, to keep the sensor get new view every millisecond, hence we have made the PIR sensor work as in motion to detect the human body and switch on/off the appliances according to presence. Thermostat using DTH11 is built for checking temperature and humidity and control the state of exhaust and air conditioner. Fig. 7a shows how PIR sensor and thermostat interact with arduino to control the appliances. Fig.7b shows the prototype model of smart sensing through PIR sensor.

Figure 7a. Flow diagram for smart-sensing

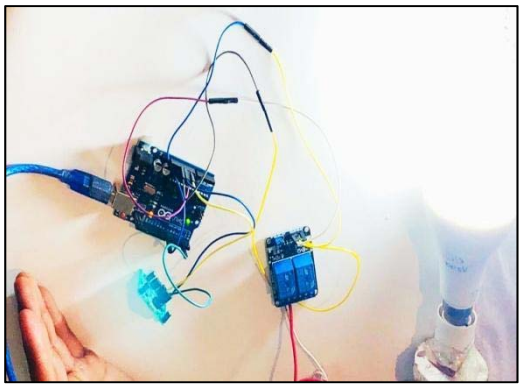

Figure 7b. Prototype model built for motion detection.

Scheduling Appliances for specified routine

The system has an additional feature to schedule automation in the lab by specific date, time and routine wise with start and end time range. This can be manually set using the mobile application or by means of a voice order through Alexa echo. Figure 8a. shows the Alexa stimulator for scheduling a routine for a specific appliance, for example we are scheduling the lab server to switch on at 8 in the morning for 20 minutes every Monday. Figure 8b shows the firebase updates made by lambda function.

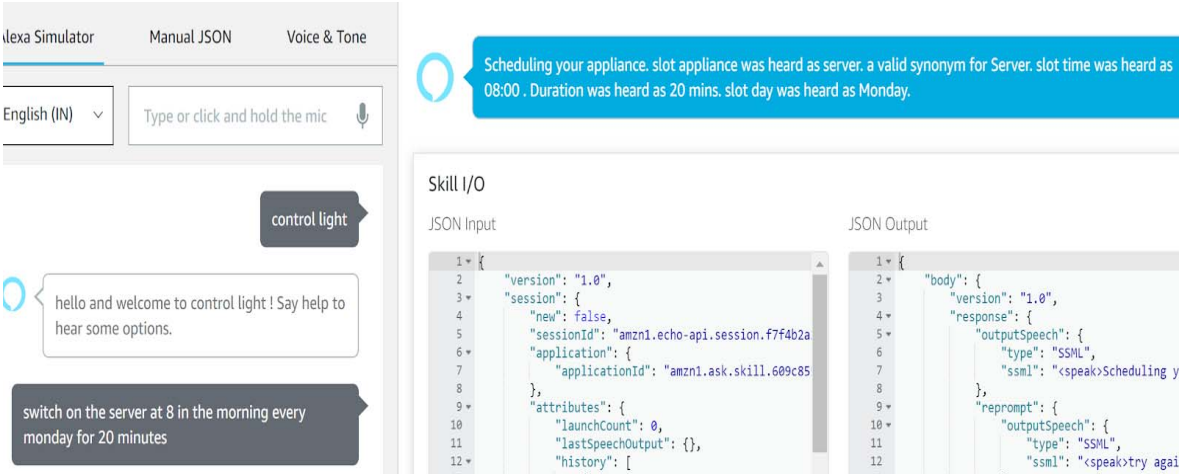

Figure 8a. Alexa stimulator for scheduling routine of the Server.

Figure 8b. Updated Firebase values, by lambda function

Biometric Digital Door Lock

Tinkering Lab is an advancement lab utilized for task work by the students and for security designs is bolted. To facilitate the way to open the lab as and when required by the students eliminating an extra individual in-charge, the possibility of computerized lock is proposed. The lab has mostly two sorts of users - Registered users i.e. college understudies/staff and Non-enrolled i.e. outside guests. Enlisted users utilize the biometric machine to open the entryway while for the visitors, a touch camera empowered screen is given where they can enter their subtleties so as to open the entryway. The entered subtleties i.e. name, telephone number alongside their photograph is sent to the super administrator through message, who will at that point open the entryway using the android application from anyplace. Figure 9a. shows the mechanism of how our Biometric Door Lock works for both registered and non-registered users. Figure 9b. shows the prototype model of fingerprint identification via Arduino.

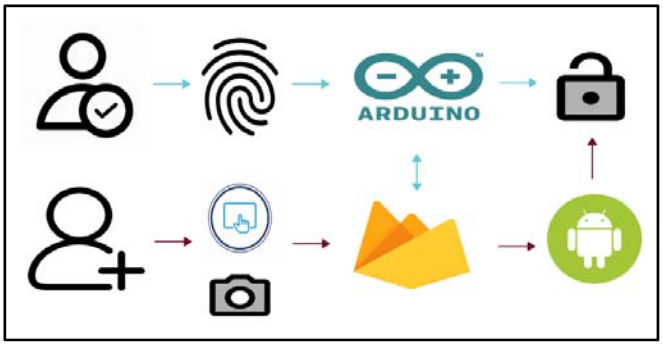

Figure 9a. Flow Diagram for Biometric Door Lock Access

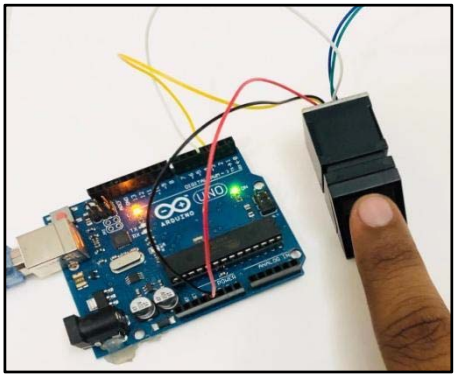

Figure 9b. Prototype model of biometric sensing

The following is a code snippet for identification of fingerprint:

```
// Identification of fingerprint
  if (fps.IsPressFinger())
  {
    fps.CaptureFinger(false);
    id =
fps.Identify1_N();
```

```
   lcd.clear();
   lcd.print("Thanks");
lcd.setCursor(0,2); lcd.print(Reg[id]); ESP.println(Reg[id]);
   Serial.println("Sent
entry data to firebase");
}
else
 {
   fps.SetLED(false);
   lcd.clear();
   lcd.setCursor(0,2);
   lcd.print("Please
Press Finger again");
 }
}
```

IV. RESULT ANALYSIS

The model has a set of metrics and visualizations which can be viewed on the mobile application and aims to capture the following thereby helping in optimizing the usage of lab access:

- Number of students using the lab
- Department wise weekly/monthly analysis of students
- Calculating the time spent by each student
- Calculating the peak hours
- Human asset improvement
- Energy Reduction

Lab Utilization Analysis

Figure 10 shows the analysis tab of our GUI Application which has the features for analyzing the most frequent visitors, hour-wise usage of the lab that is at what time of the day the lab is maximum used and it can also analyse the power consumption for the week. Figure 11 shows the graph of departmental wise usage of the lab in the first week of September. The analysis shows that this lab is maximum used by Electronics student. Figure 12 shows the analysis of hour-wise utilization of the lab in the whole day for a week. We observed that the peak hour of using the lab was at 1:30 PM for first three weeks of September 2019.

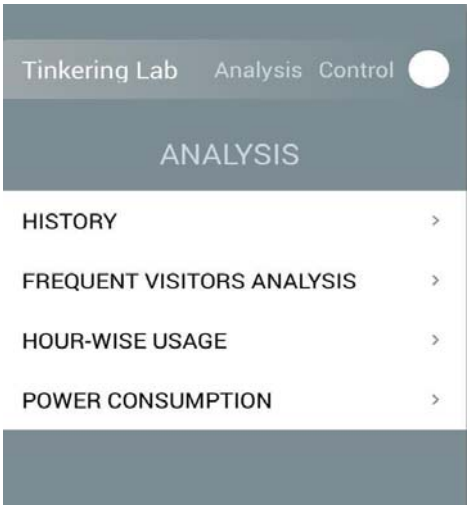

Figure 10. Analysis page of the application

Budget analysis

WTAS is an integrated solution aligning to the global goals of investing in scientific research and innovation, and efficient management of energy resources. The analysis generated after the deployment of WTAS, have shown a significant reduction in electricity consumption by 30% because of the facility of time-based main server, and AC temperature control via thermostat. Recording and calculating the peak time when the students use the lab has helped in allocation of lab technicians and faculty efficiently. Door lock has increased the security of the lab and most importantly eliminated the need of a door-in charge since now the door can be unlocked via mobile application remotely by the admin. Studying department wise report has helped in equipping the lab with only required resources for project work hence saving cost and reducing resource wastage. The deployment of WTAS is worthy because along with the above advantages, it is also significantly less expensive than the similar technology provided by other market competitors as shown in figure 13.

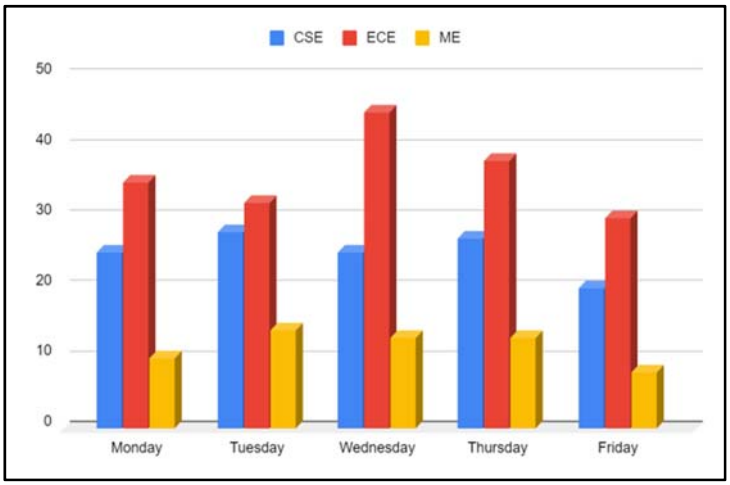

Figure 11. Department wise analysis from 2nd -6th September 2019

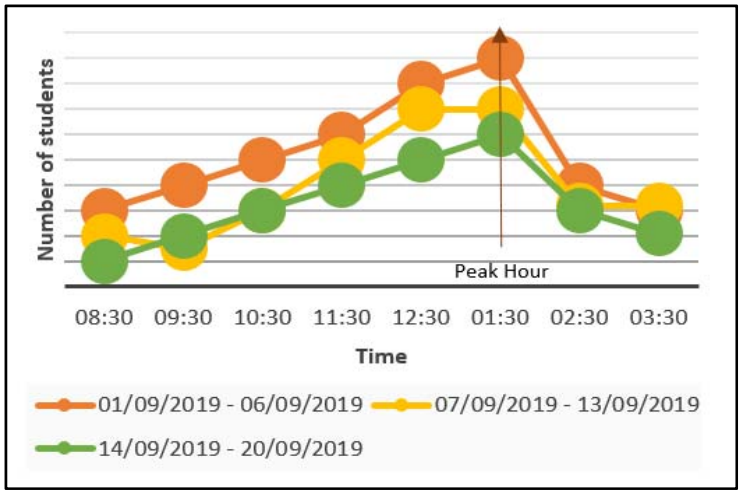

Figure 12. Peak hour analysis from 1st -20th September 2019

CAMPARATIVE BUDGET ANALYSIS		
	MARKET	WTAS
ANDROID APP APPLIANCE CONTROL	₹ 10,000	₹ 3,200
SENSOR BASED CONTROL	₹ 4,000	₹ 1,800
THEMOSTAT AC CONTROL	₹ 1,100	₹ 600
BIOMETRIC GATE LOCK	₹ 15,000	₹ 8,530
TOTAL	₹ 30,100	₹ 14,130

Figure 13. Budget Analysis- Market available customized models vs proposed WTAS model

V. CONCLUSION

IoT based Wireless Tinkering Lab Automation system (WTAS) has brought more convenience, security and resource optimization to the University. The android based mobile application facilitates electrical appliances ON/OFF, door unlock lock via internet and utilization graph. Using android application user can control and monitor the smart lab environment. This lab automation system for The NorthCap University is required because sometimes they are no door attendant and lab need to be unlocked, providing a digital lock that can be unlocked via mobile application provides convenience. Examination will assist the college with taking better choices for giving assets and expects. Lab servers can be timed for working hours, AC temperature controls are enabled and furthermore once in a while students forget to switch off the appliances when there is no need to use, in all the above situations, the automation system is used to reduce the wastage of electricity.

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