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Building Automation and Context Aware Energy Consumption using IoT – Smart Campus

Manu Jain[1], Asmita Varma[2], N Kaushik and Kayalvizhi Jayavel[3]

Department of Information Technology, SRM University, Chennai, India.

[1]Orcid: 0000-0001-6465-1353

Sivanathan K[4]
Department of Mechatronics Engineering, SRM University, Chennai, India.

[4]Orcid: 0000-0002-5302-030X

Abstract

The world is now heading towards a busier lifestyle. Taking care of upcoming challenges in life everyone expects the day to day works to be handled with less effort. Here automation plays an important role in easing the lifestyle of people. Automation takes care of getting the task done without human involvement. Automation implied using Internet of Things (IoT) makes the device smarter and allow them act according to the context which brings in the context awareness of the automated energy efficient systems. Context aware system is important for efficient use of energy and automation allows the system to work with less manual support. This paper proposes a system that uses IoT to design an automated module to control room appliances and a context tracing system to trace the environment of the room for efficient automated use of appliances and hence efficient energy usage. The traditional system of energy consumptions includes huge amount of energy wastage as well as huge cost. Rate at which the traditional system is wasting the energy resources it is likely face an energy crisis soon. Automation can be a decent solution to to such hazardous problems.

Keywords: Automation, Internet of Things (IoT), Context Aware energy management, Energy control, Energy crisis.

INTRODUCTION

Automation, anywhere we look around this word is embracing our lives with simplicity and accuracy. Any task we can think of is now automated to some extent. Our houses can viewed as a showroom of automation technology. Home automation is rapidly emerging field with lots of scope in development. Whenever we talk about home automation we cannot miss the word Internet of Things (IoT). IoT has become the best solution to automation and has proved how it can change the world with its strong concepts. IoT allows any system to omit the human involvement with the intelligence of machines or devices.

Internet of Things (IoT) is network of devices communicating with each over internet or some other communication to make the system smart. A smart system created using the concepts of IoT can become helpful for automation, data management, retail, green energy, etc. [4]. IoT as a term was first coined in 1985. It was first used by Peter T. Lewis at Federal Communication Commission (FCC) [5]. According to a survey it is expected to have 20.8 billion devices in field of internet of things [6].

IoT is expected to create this world a smart network that allows the information of different devices all over the world to be shared with each other in order to improve the lifestyle of mankind. Automation is a small part of this large scope of IoT but still automation is a big contribution to it. Automation has been already supported by other big technologies such as Big data analytics and Cloud computing. These technologies are reaching their saturation slowly. IoT stands as a gate for these technology's progress in the future. Most of the technical industries including the big technology players of the world are moving their attention towards IoT. A survey from Gartner, Inc. shows that 43% of the organizations have already started using or have planned to use IoT [7]. IoT with such a large scope can be proved as life changing.

IoT is a great supportive hand for automation as discussed above. The large scope of IoT and its concepts of smart communication between the devices can take the automation to a new level. The trend of automation is increasing day by day in technical industries as well as the public. Automation is fascinating as well as useful. In the last few years Home automation has emerged as a field with enormous scope in technology. Lots of work has been already done in the field of home automation which we are going to discuss in the section 2 of this paper. Despite of the work already done in the field of home automation, most of the home automation systems

available tends to ignore the energy consumption aspect. Energy is generated from rapidly decreasing resources. Energy conservation is an important feature to be included in all the available home automation systems.

Energy is an important resource of everyone's livelihood and it is degrading day by day. We are approaching the day of energy crisis with very quick steps. The energy consumption in commercial buildings is projected to grow by 40% to 1880 TWh in the next 25 years [1]. The wastage of energy in automation is a serious issue. The 30% of the usage by commercial building is inefficient and unnecessary [2]. The automation by efficient usage can help in saving 10% of this wastage which results in the collective saving of about 40 Billion dollars [3]. The solution offered to the problem of wastage of energy in buildings in this paper is achieved with the continuous context awareness and automated control of the appliances.

The module proposed in this paper has been developed to fulfill the needs of home automation along with the conservation of energy by optimizing the use of appliances according to the situation and the environment of the room. The module is oriented towards saving energy along with the functionalities for a good automation of appliances in the room. The energy control in the module is achieved by gaining the knowledge about the context which helps the system to decide which appliance of the room is required at the particular moment. The module also provides good automation functionality and it is flexible enough to work according to the user. The module is customizable and can be deployed to different types of rooms and also it is cost effective as compared to other available products for home automation in market. Proposed module being an energy conservative home automation system is highly cost-effective as the energy saved is priceless for the future generations.

RALTED WORKS

Automation being the new pattern of interest has pulled in numerous technical associations and giants towards itself. Many of such associations and partnerships have put huge endeavors for the generation and research of IoT. The endeavors of them are basically centered around giving simple openness and some are additionally centered around making an "across the board" gadget that can deal with all little everyday activities of any individual.

Various items with brilliant characteristics are brought to the market by a few unique organizations, partnerships, and associations. Some of such items are Google Home (section 2.1), Amazon Echo (section 2.2), Apple Home Kit, ivee voice, Cubic, and so forth. Every one of these gadgets is effortlessly accessible in the market with a few exceptional and distinctive features. All of these mentioned devices emphasize on carrying out the everyday business of an individual. The Room Automation module has one additional feature that of keeping the framework productive and at the same time helping society in sparing enormous measure of energy.

A. Google Home

Google, Inc. a well-established technology conglomerate has developed Google Home as an IoT based Home automation device [8]. Home Automaton is one of the major as well as the central feature of Google Home. It also has variety of other features such as web streaming, playing music using Google Play Music, iHeartRadio [9], placing order of everyday essentials [10] and so much more. Google Home works on a Linux based OS using dual-core ARM-based microprocessor, 4GB of RAM and a dual-band 802.11ac Wi-Fi chip [11]. Google has partnered with Nest, SmartThings, Philips Hue, and IFTTT for the purpose of Home Automation.

B. Amazon Echo

Amazon Echo is a product of Amazon.com which is also an established corporation and have a big name in the domain of e-commerce and cloud hosting [12]. Amazon Echo is a smart voice enabled wireless speaker used for Home Automation and other features very similar to the Google Home product by Google but was launched about two years before Google Home.

Amazon Echo has also partnered with the companies like Philips Hue, Belkin Wemo, and Smart Things for the smart device making. It is capable of doing the chores of making a to-do list, doing the math, playing music, setting alarms and so much more. The listed set of activities and additional activities are performed by the competing product Google Home as well. Certain organizational distinctions make Google Home a better product than Amazon Echo in terms of functionality, accuracy and efficiency but none the less Amazon Echo was one of the biggest milestone in the field of implementation of AI. The Echo hardware components includes a Texas Instruments DM3725 ARM Cortex-A8 processor, 256MB of LPDDR1 RAM and 4GB of storage space [13].

ROOM AUTOMATION AND CONTEX DETECTION

Automation has become a necessity over the years. Now we are living in an era where it is important to keep on improving the automation techniques in order to reduce the threats to security. Automation is properly defined as the technique to improve the work performance without a manual support. Automation though having a general definition, is divided into multiple domains such as Home automation, Factory automation, Business automation and so on. This paper focuses on a technique or model for Room/Home automation. Home automation is a domain which has an essential amount of work already done in it. Home automation is now more focused on the other aspects which are readily termed as the drawbacks of

automation. Home automation was oriented towards the ease of performing tasks such automating the switches, controlling of appliances according to room environment etc. Home automation now requires to take in accounts the energy aspects. Energy conservation has started to become a mandatory feature of every automation product. The module proposed in this paper for Room automation is designed to maintain the smart automation of the rooms using IoT alongside controlling the energy consumption to reduce the amount of energy consumed compared to the traditional Room automation models.

To control the energy consumption of an automated room contextual knowledge of the room can be proven as a very crucial breakthrough. The proposed module is a context-aware system that controls the room appliances according to the availability of the context. The module is designed to be controlled in two modes, Manual and Auto. In the manual operating mode, the module is designed to take user commands from a smartphone application. The smartphone application sends the user command to the processor or the controller board which operates the room appliances. In the auto operating mode, the module takes the data from a sensor bed which is designed to collect the data about the room's environment. The module also takes data from a camera deployed in it which detects human presence. The contextual data collected from the sensor bed and the camera are properly interpreted by the processor or the controller board. The controller according to the interpreted data manipulates the room appliances to save energy. The sensor bed includes the IR (infrared) sensors to count the number of people present inside the particular room. These IR sensor's data is analyzed even when the system is working in the manual operating mode. If the count from the IR sensors is zero all the appliances of the room are kept OFF. The smartphone application is also updated with the operating status of appliances. The operating status of appliances on the smartphone allows the user to keep track of the appliances with ease. The smartphone application plays an important role in the module. It allows the room to be easily monitored and controlled. Figure 1 shows the general architecture of the module is proposed here.

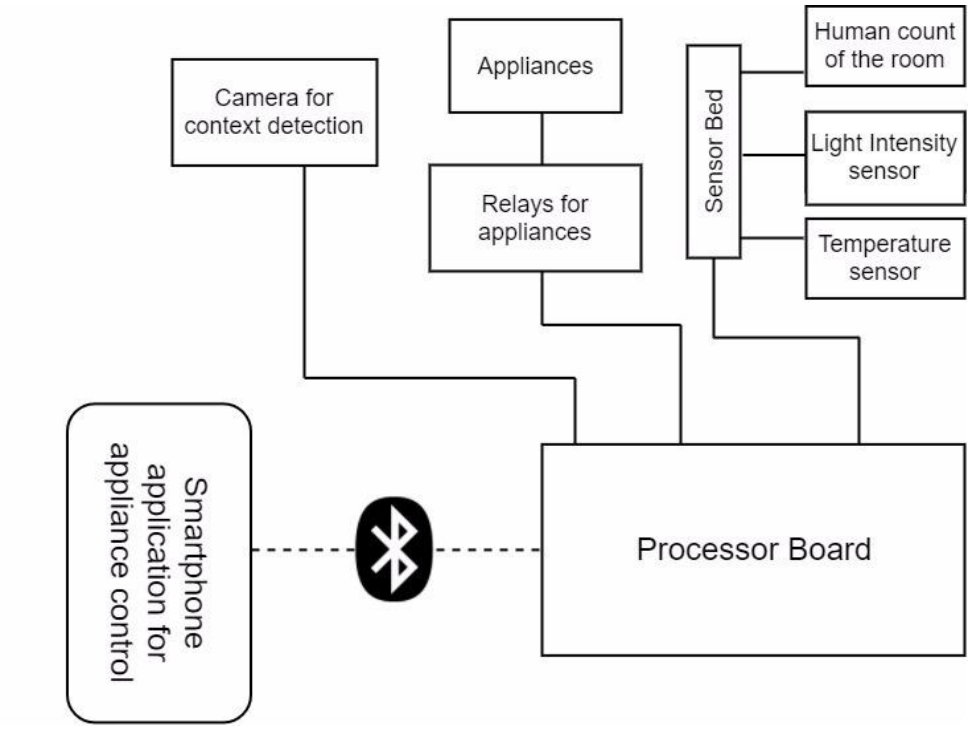

Figure 1: General architecture

We expect an automated system to perform tasks without human involvement. We expect the system to perform tasks according to usual human intentions. For an example, as we enter a room, we assume that the first usual human intention would be to switch on the lights. Most of the fully automated system would do so. But it is important to take into account the situations which may ask for variations in human intentions. For example, we may not require the lights to turn on if there is enough light from the windows or user may want to turn off the light when they are asleep. Above situations require the automated system to be designed in such a way that the users are allowed to override the system's command with their intention. The proposed system is also designed to have the automatic and manual operating modes so that users can command the system according to their convenience.

The automation in real time situation requires the collection and interpretation of real time data. Machines need to communicate with other machines and also act according to it. IoT is a good

solution to automation. IoT is promising for monitoring, controlling and communication of devices connected to a network [14]. For the collection and interpretation of real time data IoT is the suitable technology. The proposed module uses IoT to detect the context of the room. In order to control the appliances of a room in automated mode, context detection is important. Context contains both the environmental conditions of the room and physical presence of humans in the room. Multiple sensors are used in the module for the detection of environmental conditions such as the temperature of the room and Light intensity in the room. For the detection of physical presence of human, IR sensors are used, as mentioned above, for getting the total count of humans inside the room. The total count of human inside the room does not fulfill the requirements of the module as it does not provide the specific information such as which part of the room is used by the people and accordingly what are the appliances they may use. A camera is deployed in the room which detects the presence of human in different parts of the room. The recordings from the camera are not saved in the device and are removed after the interpretation of data is over, making the use of camera in room secure.

Room automation module is designed for automatic control over the room appliances without a human support. Module also includes a context detection system to provide better functionality. Module also includes a manual control option, as mentioned above, that allows the users to overwrite their intentions over the system's commands. All these functionalities converge to an important advantage of conservation of energy used by the appliances. As discussed previously the automation is diverting towards other important aspects where energy is a major. Context detection in this module allows the system to control appliances according to the need. The context awareness technique allows the system to conserve energy by using only those appliances which are needed at that moment.

A. Prototype

A design explains the theoretical functionality of a system. To prove the statement of design, prototypes are build. A prototype is a model of the system which can be deployed in an actual work area. A prototype has been made for the above designed module. The prototype uses a camera for context detection and some sensors for the environmental information of the room. The prototype can be controlled using a smartphone application which is specially designed for this prototype. The smartphone application monitors the appliances and records the status of the state of appliances. The module works in two operating modes, as mentioned above, manual and auto. In manual mode the commands are sent by user from the smartphone application. In auto mode the information from camera and the data from sensors is used smartly to control the appliances. The state of the appliances is updated in the smartphone application in auto mode also. The smartphone application sends the data to the processor board using BLE (Bluetooth low energy) protocol and also the processor board sends the state of the appliances to the smartphone application using the same BLE protocol. BLE protocol has a range of around 100 meters which protects the system from getting controlled from large distances. BLE is a fast technology for transfer of a good amount of data using low energy.

The implementation of the prototype is fulfilled using specific hardware and with a smart data interpretation and actuation logic which is programmed in a specific language. The programming language is dependent on the hardware used for the implementation. Figure 2 shows the circuit diagram of the prototype prepared for the demonstration of the module proposed. The components required for building the prototype are:

- Raspberry Pi: Raspberry Pi is small computer integrated on a single board. It can attach the peripherals such as mice, keyboards, etc. Raspberry Pi has a 32 bit 900 MHz processor. The processor have 4 cores which is named as the ARM Cortex-A7 processor [15]. Raspberry supports many operating systems but the main operating system used in this prototype is Raspbian. The Raspberry Pi is the processing board which runs a Python script that allows the board to receive commands from the smartphone application and also control the room appliances.
- Pi camera: Pi camera is an image sensor that connects to any version of Raspberry Pi. Pi camera v2 is the module that is used in this prototype. It is an 8 megapixel HD camera developed on an image sensor by Sony [16]. Pi camera in this prototype is used to take the images of the room which is then processed for the detection of human in the room. The images are processed on the Raspberry Pi using OpenCV and a Python script which runs on the OpenCV. OpenCV is a library that includes 2500 optimized algorithms for the image processing [17]. OpenCV's algorithms are suitable for the context detection functionality of the prototype.
- HC-05 Bluetooth module: HC-05 is the hardware that implements the BLE protocol. It acts as the communication module between the smartphone application and the Raspberry Pi processor. It completes the network of the BLE protocol and allows the edge devices in the networks to transfer the data [18].
- IR sensor: IR (Infrared) sensors use the IR receiver and transmitter to calculate the distance of objects from the time taken by the ray to come back to receiver after the transmission. This prototype uses this feature of IR sensors to count the number of people present inside the room. The IR sensor also works in the manual operating mode of the prototype to conserve the energy by turning off the appliances when no one is present inside the room.
- LM35 Temperature sensor: LM35 sensor senses the

environmental temperature of the room. The number of LM35 sensors required depends on the room where the prototype is to be deployed. Multiple sensors are used to get the accurate data. The LM35 sensor data is used to regulate the ACs and the fans of the room to maintain a specific temperature in the room.

- LDR sensor: The LDR (Light Dependent Resistor) or the photoresistor senses the light intensity of the room. Number of LDR sensors required is as similar to LM35 sensor depends on the deployment area. According to the data of LDR the lights of room are manipulated to provide sufficient light in the required parts of the room.

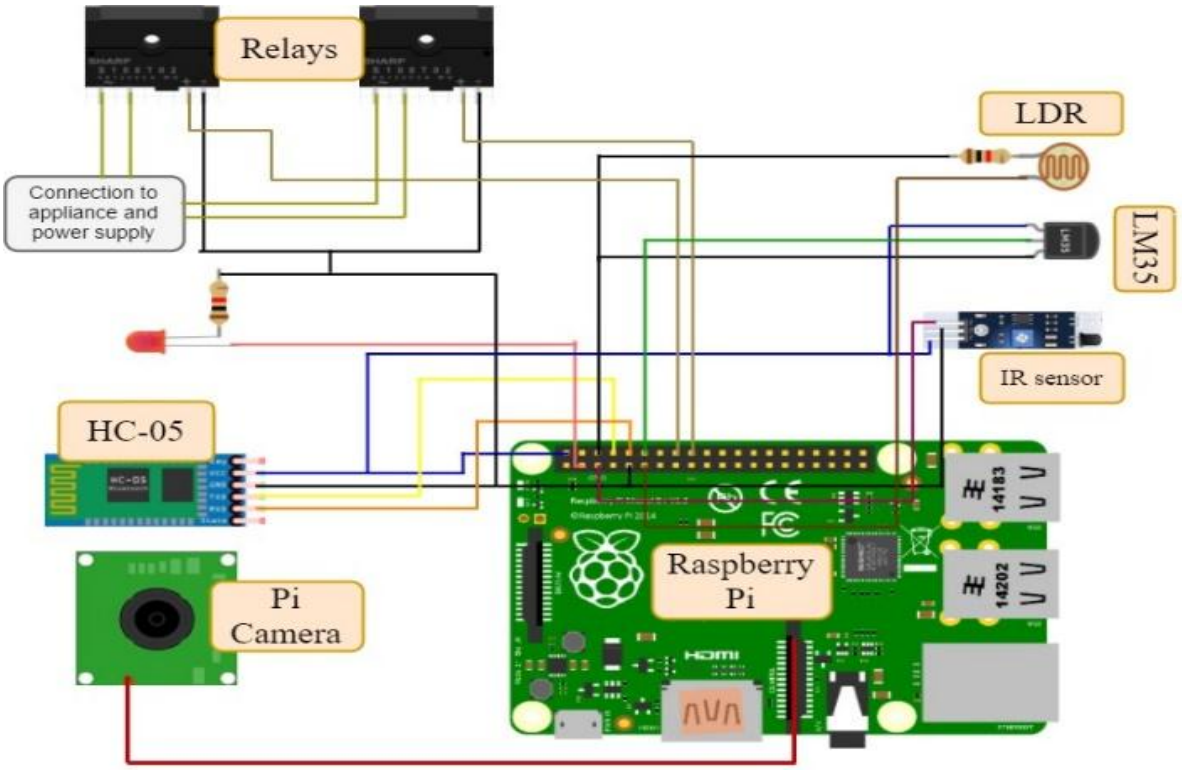

Figure 2: Circuit diagram of the prototype

- Relays: Relays are electronic switches which are controlled by the current supplied to it. This prototype uses a 5V (input) 220V (output) relays that controls the appliances of the room. The relays are turned ON and OFF depending on the power supplied to it [19].
- Android Studio: Android Studio is an IDE (Integrated Development Environment) used to develop the smartphone applications for the Android based operating systems. Android Studio was introduced in May 16, 2013 at Google I/O conference [20].

B. Processing Cycle

The processing of the module proposed in this paper is not a single flow. The processing of the module does not follow a straight flow and is diverted due to the two operating modes of the system. Many of the processes in the system takes place simultaneously and hence they are not defined in flow. This system's functionality is purely concentrated on the processing board Raspberry board and rotates around it. The Figure 3 shows the flow of the processing of the module.

1. Smartphone application takes the commands from the user and sends it to the HC-05 Bluetooth module. Smartphone application take the manual commands from the user which is sent to the Raspberry Pi through BLE protocol.
2. HC-05 Bluetooth module is the intermediate in the communication between smartphone application and the Raspberry pi.
3. Sensors collect the data of room environment and the data is recorded in the Raspberry Pi.
4. Pi camera sends the HD image of the room to the Raspberry Pi for context detection.
5. The processing board Raspberry Pi continuously runs a python script that is coded to control the appliances and receive data from smartphone application in manual mode and from sensors and pi camera in auto mode. The

Raspberry Pi analyses the image from the Pi camera in the auto and performs the appropriate action on the room appliances through the relays.

6. Relay receives the commands from the Raspberry Pi in the form of electric power according to which the appliances are controlled.
7. The status of the appliances is updated to the smartphone application by the Raspberry Pi through the HC-05 using the BLE protocol. This status of the appliances is recorded in both the Raspberry Pi's Python script as well as the smartphone application to avoid unnecessary commands such as "AC ON" when the AC is already ON.

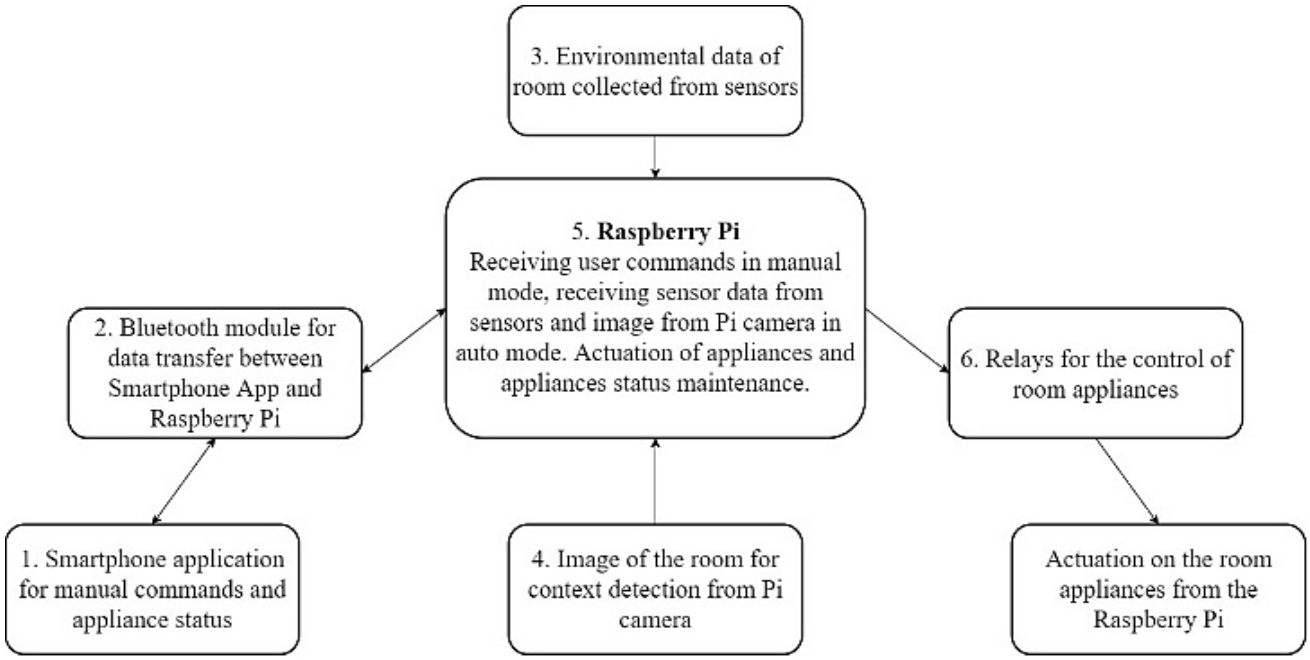

Figure 3: Processing flow

FUTURE WORKS

World is now a smaller place compared to our earlier days. We have large geological distances but we have figured out enormous number of ways to communicate over it. Automation since its earlier days has flourished our lifestyles, workplace, home, etc. Automation despite of being an old concept it is still a trending field in technical applications. Automation has improved the lifestyle of billions of people and efficiency of hundreds of organization. Though Automation has already been explored for large extent it is never wrong to say there is always a room for improvement. The module proposed here has been designed using the latest technical concepts that supports home automation but many voids are still available in the module which can fulfilled with a good amount of future work.

A. Incorporation of cloud analytics

Sensors generate large amount of data. The data generated by the system can be very useful for the prediction of some hazardous situations. For an example, the data of temperature sensor can be used for the detection of a situation of fire if the upcoming data follows the trend of fire situation occurred previously. The cloud analytics must be merged with the concept of machine learning to allow the system to react quickly in the situation. If the all the processing of stream data is done on the cloud it will require a large amount of time for the home automation system to react to situations.

B. Incorporation of edge analytics

Sensor data are required to be analyzed quickly in order to react to the situation as fast as possible. Sending the sensor data to cloud for analysis purpose is time consuming as well as costly. IoT has emerged with a new concept in the field of analytics. Edge analytics, it is the solution to the drawbacks of cloud computing. Edge analytics is the analysis of real time data on the edge devices [21]. The proposed module can use the edge analysis concept to analyze the sensor data quickly on the processor board itself. The analyzed data can be used to train the system using the machine learning concepts.

C. Extension to smart home implementation

The paper describes the module for the automation of a room.

The module can be deployed in all the rooms of a house with some amount of customization. Even if the module is deployed in all the rooms of a house we cannot call it smart home. We can think of and smarter implementation of this module where all the modules deployed in different room can communicate with each other. The modules can share data about context which can be used create a security system for the home. The system proposed in the paper is scalable and can include many functionalities which extends the system as a smart home system.

D. Using better protocols for communication

Communication protocols defines define the efficiency and security of every automation system. The better the protocol is better will be the system's security. The protocol used in the module proposed fulfill the requirements of the functionality of module but not the features. The protocol used in module is BLE (Bluetooth Low Energy) which is very reliable but not secure. The data transfer speed of the BLE protocol is slow and also it can only one connection at a time which can be both an advantage and disadvantage. There will be some situations when two different users want to use two different appliances. These situations are not supported by BLE protocol as it only supports one-to-one communication.

With the growing scope of IoT everyday IoT requires to have protocols which conserve less energy and are easily implementable using the readily available models of communication. Some of such lightweight protocols which have been developed specifically for the IoT implementation are CoAP and MQTT [22].

CoAP (Constraint Application Protocol) is the protocol developed for IoT applications. CoAP is a lightweight protocols that uses HTML model of document transfer. It is designed for the need of the constraint. CoAP works with REST model using server-client model and can be integrated easily with HTML as they work on same implementation models. CoAP is secure protocol with 3072-bit RSA keys equivalent DTLS parameters [23].

MQTT (Message Queue Telemetry Transport) is another protocol which has been redesigned for the purpose of IoT and has been made lightweight and low power consuming for IoT applications. MQTT uses the traditional message transfer method for communication but with a faster speed and secure communication. It works on a publish/subscribe model and can provide one-to-one, one-to-many and many-to-many M2M communication [24].

CONCLUSION

Internet of things is an inclining field of innovation. It can be the best answer for the problems of automation. Maximum products for automation have a concentrated focus on automating the mechanism of the task and tend to ignore other hazardous aspects which have become a drawback of these products. This is vital to divert the concentration of ventures towards the increasing energy crisis in the world. Energy is being produced by the important resources which are diminishing every day. It is critical for each commercial sector to be energy efficient alongside its automation. IoT fills in as a decent solution for energy control and conservation. Coordination of the IoT with Cloud analytics or Edge analytics along with Machine learning can upset the world in the division of automation with an additional advantage of saving energy.

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