Application of IoT for Intelligent Home Automation System

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Abstract- **In recent time, internet has revolutionized the whole technology. It is acting as a backbone for the information technology. Subsequently, IoT has seen considerable development as internet became more common. Similarly, research is being carried out to make IoT applications more user friendly especially in web based and android technologies. Internet of thing gives an extensive control by enabling to control remotely the switching of electronics devices such as fan, water pump, cameras, TV etc. In this paper, an IoT based home automation system for remotely controlling the home equipment's is proposed. We are using Google Assistant and Amazon Alexa to control and monitor the electrical appliances with voice command through internet which gives more space for controlling electrical appliances. In automations, things are automatically controlled usually the basic tasks of turning ON/OFF of devices. Here we can not only turn on/off basic devices but can also regulate the speed of fan by setting it at i.e. 30%, 60 and 100%. This makes our IoT based system more intelligent to control electronic devices both from within the home and outside the home as long as internet is available. This will help to reduce the wastage of electricity and save human energy.**

Index Terms-- **Home Automation, Relay, Node-MCU (ESP32), Internet of Things (IoT), Amazon Alexa and Google Assistant, Voice Control, Smartphone.**

I.INTRODUCTION

Human Machine Interaction (HMI) [1]–[3] has gradually increase in the last century. The major breakthrough is marked with the advent of the computer. It has revolutionized every field of life. Recently, internet has made worldwide communication more convenient and efficient. Research in HMI has progressed, and internet has been used for integrating of different electronic devices together. The devices are controlled remotely by us from anywhere through internet. This technology is known as Internet of things (IOT) [4]–[6]. The objective of the application presented in this paper is to remotely control electronics devices from anywhere. It gives us more flexible control by controlling the speed of the fan.

IoT has very wide applications in many different fields. Its Area of applications ranges from very simple level to macro level which includes ecommerce [7], coal mines [8], smart grid [10], laboratory control and monitoring [11], agriculture [12] and a number of other fields [13]-[16]. Technology is improving day by day and there has been a lot development but energy is still one major issue. Power consumption is of concern in today's world. It has been reported that the information and communication technology (ICT) solely consumes 4.7% electricity of the world and this percentage is likely to reach 10 % [17]–[19]. The population of India which makes 17% of the world population has very less reserves of energy resources i.e. about 0.6%, 0.4% and 7% of the total gas, oil and coal, respectively, on earth [20]. On the other hand, the rapid growth in ICT industry in India has drastically increased the consumption of electricity to 31 TWh from 24 TWh over a period of five years (from 2009-2014). According to rough estimate in 2015, the electricity consumption was 6.5% world [19].

In this paper, a smart and intelligent home automation system proposed which is developed in order to control the electricity consumption by controlling the consumption of power more efficiently. It will help us to reduce the electricity consumption at consumer ends, make our equipment secure by helping the user to control the equipment remotely. We have discussed smart home automation system in section II, proposed system design and its implementation in section III, implemented model and working procedure in section IV and conclusion in section V.

II.SMART HOME AUTOMATION SYSTEM

Energy demand is rising with time. Electric power is necessary for the function of the electronic related equipment.
In today's busy life, life is unimaginable without electricity and we are getting more dependent on electronics devices. Consequently, the demand and cost of electricity has increased.

Therefore, Home automation has become a well-researched area. An efficient and intelligent home automation will help us control the home appliances remotely using IoT [21] – [24]. It also benefits disabled and old aged people by controlling fan, bulb etc. without any physical connection [9] [25]. There has already been a lot of research on home automation [21], [23], [24],[26]–[28]. The Previously designed systems are mostly using DTMF or Bluetooth [9], [21], [26], [27], [29]–[31]. There are short comings with both these systems. DTMF requires dedicated PSTN channel of communicating between the controller and main supply units. In case of Bluetooth, communication range is short.

MQTT (Message Queuing Telemetry Transport) one of the most popular protocol, is used to send and receive information from the sensor [28]. MQTT protocol is used for establishing remote connections i.e. wireless over Wi-Fi, Bluetooth in a network where the devices has limitations and constraints in terms of resources and bandwidth of network. It is mostly implemented on transport network which is lossless, ordered and run bidirectional such TCP/IP. MQTT is OASIS standard as well as recommended by ISO i.e. ISO/IEC 20922. MQTT protocol has two main elements one is message broker and another is number of clients. A message broker is basically a server receives messages from different clients and the sends it by routing it to the relevant destination. A client will be any device that uses MQTT library and is connected to an MQTT connection. The MQTT has three main components in following the protocol i.e. connect, publish and subscribe. The MQTT follows the publish/subscribe pattern for communication between machine to machine (M2M). The clients are characterized either as publisher i.e. message sender clients or subscriber i.e. message receiver client. The publisher and receiver never directly interact with one another rather communicate through a third party i.e. broker. /the message is sent to the broker which is sent to subscriber for which it is designated. If the relevant subscriber is offline or not subscribed; the last message is discarded otherwise it is stored and sent when the subscriber subscribes if the message is designated as retained message by the publisher. Similarly, if a relevant publisher is offline or has not published; the broker sends a cache message to the subscriber. The broker must first establish a connection between the publisher and subscriber ensuring proper connectivity b sending messages to check the availability of the clients. MQTT has many advantages. It removes any insecure client connection. It has a very large scope in terms of connections. We can establish a wide range of connections ranging from one to thousands. It is capable of maintaining the status of all clients including their security and certificates credentials. It decreases the strain on cellular or satellite network to which it is connected keeping the security intact. The sensor measures the room's temperature and humidity which is accessed through Raspberry pie. One of the home automations is designed using Raspberry pie with a user friendly web based interface to control appliances [23]. Another home automation system is using ZigBee [26].

It is been made possible through IoT to convert non-smart devices into smart device by controlling it through applications. Home automation through IoT makes it smart home by enabling us to control the appliances more robustly. For Security, homes can be monitored through cameras installed which are operated through internet. A user has greater control and can switch on/off their appliances at will to limit electricity consumption and reduce cost. There can be additional features in our smart home such intruder detection in case someone enters the home through use of sensors and cameras. The system can be made more intelligent, for instance, automatically turn on fan and lights when a person enters a room.

Such idea serves as the main purpose for developing an IoT based home automation system. It is both voice control and web based application service to control monitor the different appliances of our home. It has been made more secure by adding a user-defined command which will enable the systems operation.

III. PROPOSED SYSTEM DESIGN AND ITS IMPLEMENTATION

The most vital mode of communication is speech. It is also used in man-machine interaction as inputs to the machine [32]. Amazon Alexa or Google assistant can be used together with web-based applications making a more user friendly and intelligent home automation.

It is a multimodal home automation system. Its advantage is that the control can be achieved through different modes in case one mode is ineffective. For instance, noise in the background disrupts the performance of google assistant. In this case, web-based application will still provide effective control. Hence, this model is more flexible and robust which can be seen in the architecture shown in Figure 1.

In figure 1, there is a main controller unit (a switch) with a 24 hours Wi-Fi connection which is automatically connected with the controller as programmed and there is a backup power. In case of failure in Wi-Fi connectivity, the appliances can manually control through buttons on the switch board. It has both smart control as well as manual control.

The home appliances may not be inherently smart. They can be made smart by connecting sub units with main controller. Hence, it can be accessed through google assistant or Amazon Alexa and web based IoT application. The communication maintained through Sinric. The home automation systems have following main components which are, Node-MCU (ESP32), Amazon Alexa, Sinric, Arduino Software (IDE), Relays and Load (Light Bulb and Fan).

Amazon Alexa developed from Ivona, a speech synthesizer, which was developed in Poland. It is a virtual assistant capable voice based control, playing music. Alarm notifications, playing podcasts, reading audiobooks and giving real time news updates on weather, sports etc. and other real time data. It is also capable of controlling other devices when used with third party i.e. mobile app. Its speech recognition of different natural languages based upon AI is used in home automation.
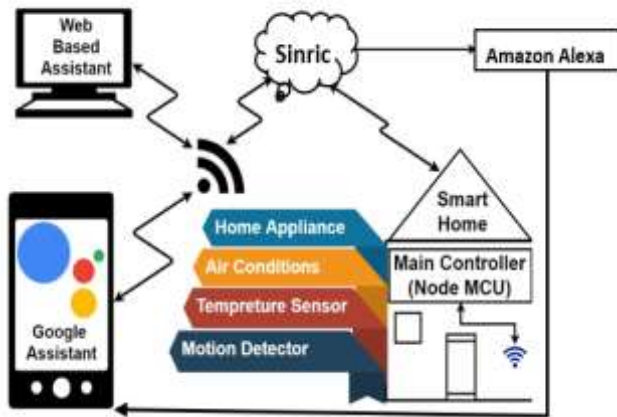
FIGURE 1. Smart home automation system architecture

Sinric pro is web based service provider used in making a connection between Alexa and IoT developmental board. It is compatible with all Amazon IoT device boards. It has python, C++, NodeJS libraries and related examples which is easy to work on and ready in short time. On a higher level, users with high skills can make their own customized setup consisting of their own rooms and schedule. REST API is used to monitor them.

Arduino Software (IDE) refers to Arduino Integrated Development Environment. It is an open source software compatible with any Arduino board. It has very simple interface consisting code editor, toolbar and a status bar. There are built in libraries and complete examples for some small projects. The software can be operated on Window, Linux, and Mac OS X. It has been designed in such a ways that everyone children, hobbyist, engineer and experts can work on it make electronic systems and develop prototypes. Arduino coding language is very simple. It uses basic C/C++ language for writing codes.

Node-MCU (ESP 32) is development board with different modules integrated on one board. It is an open source which is very flexible which makes it very popular in building IoT based applications. The feature of interest is its Wi-Fi capabilities and low cost. The computation time is low thus high processing speed in performing tasks and use lua script.

Amazon Alexa application is used to control home appliances through voice and also soft triggers provided that Wi-Fi connectivity is enabled in the whole circuit. In case, Wi-Fi failure, manual switch buttons can be used. Amazon Alexa also displays our daily, weekly and monthly consumption of power.

Sinrric is a web-based service provider used to develop a connection between IoT our main controller unit i.e. Node-MCU ESP32 and mobile application. It functions as MQTT broker. MQTT a popular protocol in IoT used for sending and receiving of feed data [28]. Its computation time is less therefore data is transferred at a faster rate. The connection is established requires 80 bytes from device to server and 20 bytes between server and device. Therefore, it is quite convenient to work with it on mobile application and conditional statements. The software used is Arduino IDE for code compilation.

IV. IMPLEMENTED MODEL & WORKING PROCEDURE:

In figure 2, complete working procedure of the smart home automation is shown. Internet connectivity is fundamental requirement to establish connectivity throughout the system. The smart home system is accessible from the web-service as well as Google assistant or Amazon Alexa. In the flowchart the complete mechanism is expressed step by step. After the successful link of internet the secure connection is being established between smart phone and ESP-32. The next step is to define the voice for the devices to be turned ON or OFF.
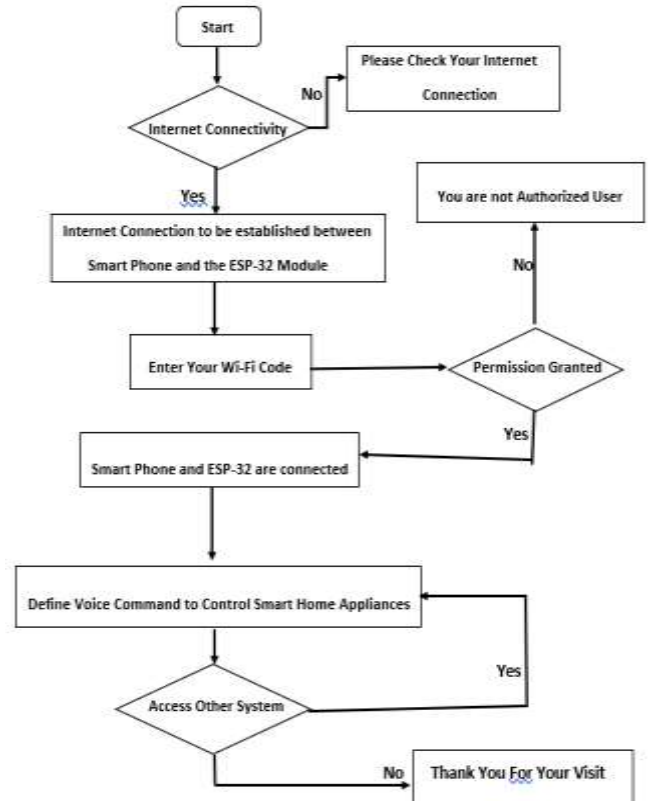

FIGURE 2. System flow on the smart home automation system using Amazon Alexa and Google Assistant

The first choice is Amazon Alexa or Google assistant to access our home automation system. The Amazon Alexa is powered by Alexa Voice Assistance (AVA), a sophisticated voice control assistant. For the purpose of processing user requests and meeting each user's specific needs, Alexa employs natural language processing methods that have been taught by Amazon's developer community and user base. The word "Alexa" can be used to activate the voice service. As previously noted, the voice command "Alexa, Turn the lights on" can be used to activate the skill or application that we have created. When Alexa is activated, a cloud-based script is launched, which in turn triggers a turn on the light. When it has finished computing, it sends Alexa a confirmation. Only the most important information is delivered to Alexa, who then relays it. Similarly, to regulate the speed of fan the voice command "Alexa, Turn the fan on" is applied to activate

the application. If user wants to change the speed of fan the voice command "Alexa, Turn the fan on at 30% speed". Therefore, the voice command can also be applied to increase the speed of fan at 60% or 100%. The designated devices can be shut down with the help of voice command. It is important to mention here that the fan speed regulation is another novel feature in this research work. However, in case of distortion due surrounding noise, web-based service can be used to access the system. The access through Amazon Alexa or Google assistant is username and password protected to prevent unauthorized access making it secure. In Figure 3, the internal architecture of the controller unit is shown.
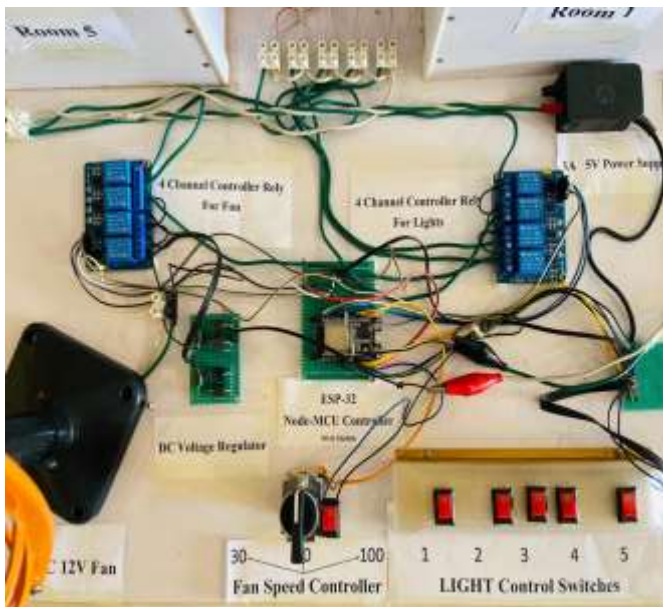

FIGURE 3. Internal Architecture of the controller unit

Once internet connection is established successfully, a user using statement command control/monitor their home appliance through Amazon Alexa and Google assistant shown in figure 4. The system is using Sinric interface to connect Amazon Alexa, Google Assistant and the ESP32 Node MCU. Our main control unit i.e. the brain of the whole system is ESP32 Node MCU. There are 8-channels relay modules connected the home appliances with our main controller. ESP-32 controller controls the switching of these relays and in turn control the appliances.

Lights, Fridge and Air conditioner are controlled through of 5 of these relay while remaining 3 relays control the fan. An additional feature is introduced i.e. to regulate the speed of the fan effectively with the help of voice command. The speed of fan is regulated efficiently as the voice command can be captured faster than writing or typing, therefore, voice command is much more efficient to implement. In this project the fan speed is regulated on three different levels. It can be seen from figure 5 that there are three different levels (30, 60 and 100) applicable in fan speed controller. These levels can be applicable with the help of simple voice command to regulate the speed of fan. There is also manual switch available in figure 5 to regulate the speed of fan as an alternate way.
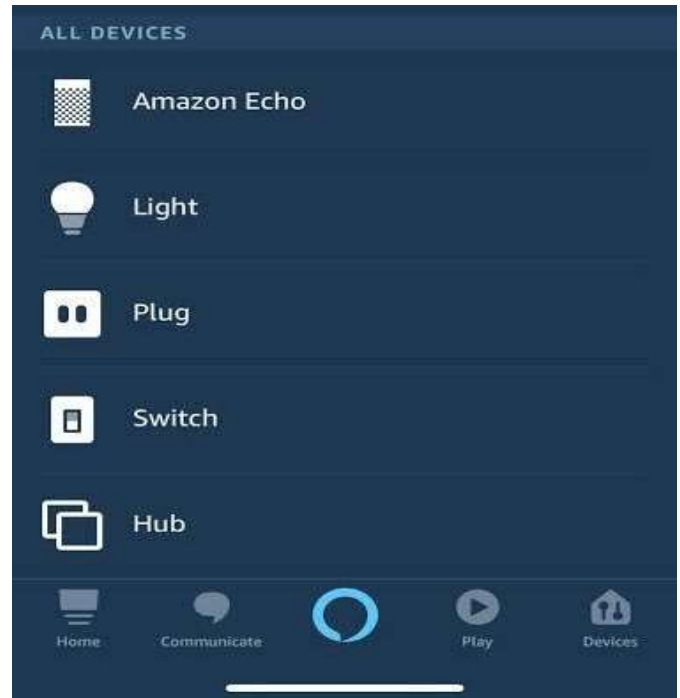

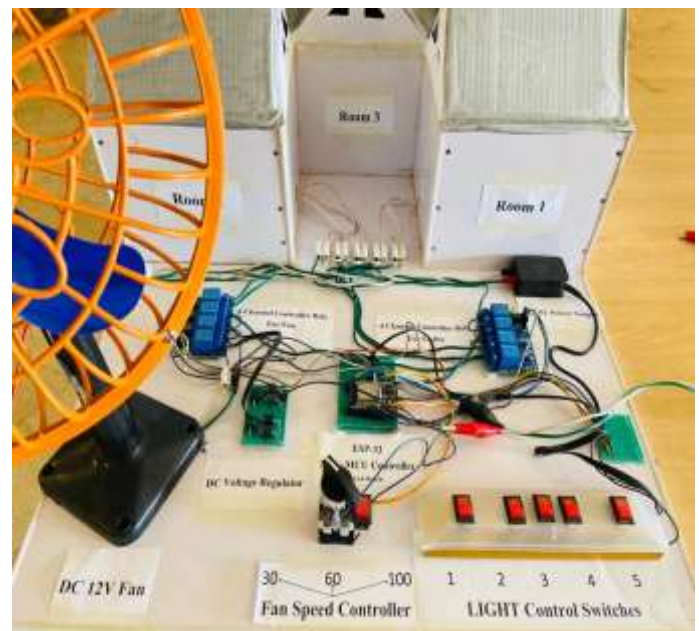FIGURE 4. IoT home automation dashboard developed on Amazon Alexa & Google Assistant

FIGURE 5. Prototype model of control unit along with the home equipment's

It is very important feature of this project which is suitable for people with a physical disability but could talk. This voice command feature could minimize and eliminate constraints to handicap accessibility and provide safe environment for the users. Therefore, in this paper, we have presented the design of the smart home automation system with the design of the primary control unit. In figure 3, a complete connection of whole system with the main control unit i.e. ESP32 is shown. To ensure

uninterrupted smooth working, a power source is required to keep the circuit in working. In figure 4, the layout developed on Amazon Alexa shows the IoT home automation dashboard.

Finally, using amazon alexa or google assistant home appliances can be controlled successfully with user command in the designed system as shown in figure 5. In figure 6, the control of room lights. In the same figure, fan speed regulation and control through manual switches is shown. The system is quite flexible, and any appliance can be connected with the control unit.

V.CONCLUSION

In this paper, a design of a smart home automation system with a step by step procedure is presented. Any home appliance can be made smart and intelligent device through the control unit designed using the IoT. The hardware part is presented here which shows experimentally the working of the proposed design. Switching of Home appliances like lights and fan can be seen with regulation of fan speed as well. A voice command feature has also been introduced for fan speed control. It gives us the advantage to access our smart home system remotely from anywhere using IoT. It will help us save the energy. Apart from this, it is a smart assistive system for old age and disabled people. In future, the system can be upgraded by integrating more control units thus making more intelligent, smarter and more flexible by increasing its scope.

CONFLICT OF INTEREST

The Authors declare that they have no conflicts of interest to report regarding the present study

REFERENCES

[1] P. Damacharla, A. Y. Javaid, J. J. Gallimore and V. K. Devabhaktuni, "Common Metrics to Benchmark Human-Machine Teams (HMT): A Review," in IEEE Access, vol. 6, pp. 38637-38655, 2018.

[2] O. Benderius, C. Berger and V. Malmsten Lundgren, "The Best Rated HumanMachine Interface Design for Autonomous Vehicles in the 2016 Grand Cooperative Driving Challenge," in IEEE Transactions on Intelligent Transportation Systems, vol. 19, no. 4, pp. 1302-1307, April 2018

[3] Z. Xu, R. Wang, X. Yue, T. Liu, C. Chen and S. Fang, "FaceME: Face-to-Machine Proximity Estimation Based on RSSI Difference for Mobile Industrial HumanMachine Interaction," in IEEE Transactions on Industrial Informatics, vol. 14, no. 8, pp. 3547-3558, Aug. 2018.

[4] S. Ziegler, S. Nikoletsea, S. Krco, J. Rolim and J. Fernandes, "Internet of Things and crowd sourcing - a paradigm change for the research on the Internet of Things," 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), Milan, 2015, pp. 395-399.

[5] J. Voas, B. Agresti and P. A. Laplante, "A Closer Look at IoT 's Things," in IT Professional, vol. 20, no. 3, pp. 11-14, May./Jun. 2018.

[6] Q. F. Hassan, "Introduction to the Internet of Things," in Internet of Things A to Z: Technologies and Applications , IEEE, 2018.

[7] S. Singh and N. Singh, "Internet of Things (IoT): Security challenges, business opportunities & reference architecture for E-commerce," 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), Noida, 2015, pp. 1577-1581.

[8] P. Kunkun and L. Xiangong, "Reliability Evaluation of Coal Mine Internet of Things," 2014 International Conference on Identification, Information and Knowledge in the Internet of Things, Beijing, 2014, pp. 301-302.

[9] A. J. Jara, "Wearable Internet: Powering Personal Devices with the Internet of Things Capabilities," 2014 International Conference on Identification, Information and Knowledge in the Internet of Things, Beijing, 2014, pp. 7-7

[10] Q. Wang and Y. G. Wang, "Research on Power Internet of Things Architecture for Smart Grid Demand," 2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2), Beijing, 2018, pp. 1-9.

[11] T. Sun, Y. Xu, J. Li and H. Zhang, "Research on Internet of Things Middleware Technology for Laboratory Environmental Monitoring," 2018 International Conference on Virtual Reality and Intelligent Systems (ICVRIS), Changsha, 2018, pp. 544-547.

[12] Q. F. Hassan, "Internet of Things Applications for Agriculture," in Internet of Things A to Z: Technologies and Applications , IEEE, 2018.

[13] Y. Hsieh, "Internet of Things Pillow Detecting Sleeping Quality," 2018 1st International Cognitive Cities Conference (IC3), Okinawa, 2018, pp. 266-267.

[14] Q. F. Hassan, "Implementing the Internet of Things for Renewable Energy," in Internet of Things A to Z: Technologies and Applications , IEEE, 2018.

[15] X. Li, P. Wan, H. Zhang, M. Li and Y. Jiang, "The Application Research of Internet of Things to Oil Pipeline Leak Detection," 2018 15th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAMTIP), Chengdu, China, 2018, pp. 211-214.

[16] F. A. Rachman, A. G. Putrada and M. Abdurohman, "Distributed Campus Bike Sharing System Based-on Internet of Things (IoT)," 2018 6th International Conference on Information and Communication Technology (ICoICT), Bandung, 2018, pp. 333-336.

[17] World Energy Resources, Technical Report, World Energy Council , 2016.

[18] World Energy Outlook Executive Summary,Technical Report, International Energy Agency (IEA), 2017.

[19] E. Gelenbe and Y. Caseau, "The impact of information technology on energy consumption and carbon emissions," Ubiquity, Association for Computing Machinery (ACM) 2015 (June), pp. 1-15.

[20] Draft National Energy Policy NITI Aayog, Government of India, 2017.

[21] Y. Kung, S. Liou, G. Qiu, B. Zu, Z. Wang and G. Jong, "Home monitoring system based internet of things," 2018 IEEE International Conference on Applied System Invention (ICASI), Chiba, 2018, pp. 325-327.

[22] Y. Sun, Y. Xia, H. Song and R. Bie, "Internet of Things Services for Small Towns," 2014 International Conference on Identification, Information and Knowledge in the Internet of Things, Beijing, 2014, pp. 92-95.

[23] D. Pavithra and R. Balakrishnan, "IoT based monitoring and control system for home automation,"Global Conference on Communication Technologies (GCCT), Thuckalay, 2015, pp. 169-173.

[24] H. V. Bhatnagar, P. Kumar, S. Rawat and T. Choudhury,"Implementation model of Wi-Fi based Smart Home System,"International Conference on Advances in Computing and Communication Engineering (ICACCE), Paris, 2018, pp. 23-28.

[25] M. C. Domingo, "An overview of the Internet of Things for people with disabilities," Journal of Network and Computer Applications, vol. 35, Issue 2, pp. 584-596, 2012.

[26] A. Olteanu, G. Oprina, N. Tapus and S. Zeisberg, "Enabling Mobile Devices for Home Automation Using ZigBee,"19th International Conference on Control Systems and Computer Science, Bucharest, 2013, pp. 189-195.

[27] R. Piyare and M. Tazil, "Bluetooth based home automation system using cell phone," 2011 IEEE 15th International Symposium on Consumer Electronics (ISCE), Singapore, 2011, pp. 192-195

[28] Y. Upadhyay, A. Borole and D. Dileepan, "MQTT based secured home automation system," Symposium on Colossal Data Analysis and Networking (CDAN), Indore, 2016, pp. 1-4

[29] T. Wang, Y. Li and H. Gao, "The smart home system based on TCP/IP and DTMF technology," 2008 7th World Congress on Intelligent Control and Automation, Chongqing, 2008, pp. 7686-7691.

[30] T. M. Ladwa, S. M. Ladwa, R. S. Kaarthik, A. R. Dhara and N. Dalei, "Control of remote domestic system using DTMF," International Conference on Instrumentation, Communication, Information Technology, and Biomedical Engineering 2009, Bandung, 2009, pp. 1-6

[31] N. M. Morshed, G. M. Muid-Ur-Rahman, M. R. Karim and H. U. Zaman, "Microcontroller based home automation system using Bluetooth, GSM, Wi-Fi and DTMF," 2015 International Conference on Advances in Electrical Engineering (ICAEE), Dhaka, 2015, pp. 101-104.

[32] P. Upadhyaya, O. Farooq and M. R. Abidi "Mel Scaled M-band Wavelet Filter Bank for Speech Recognition," International Journal of Speech Technology, vol. 21, no. 4, pp. 797-807, 2018.