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ThinkHome – A Smart Home Initiative

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Abstract— Smart home has evolved from exclusively referring to the centralized and semi-automated control of environmental systems. A smart home is also one of the applications of IoT. This paper presents the system architecture and methodologies used to create a new sophisticated smart home which creates user routines and predicts power consumption from the data received from the various sensors. Smart homes are those where daily household devices/ appliances can be monitored and controlled remotely. When these household devices are connected with the internet using proper network architecture and standard protocols, the system can be called as a Smart Home in IoT environment. This paper not only presents various problems and challenges in IoT and Smart Homes but also provides solutions that would help overcome those problems and challenges.

Keywords— Internet of Things (IoT), Smart Home, Amazon Web Service (AWS), Radio Frequency Identification (RFID), Linear Regression, Gradient Descent Algorithm, Amazon Alexa Voice Service (AVS), If This Then That service (IFTTT)

I. INTRODUCTION

As the days progress, the technology also progresses. All the devices around us have got smarter and sharper than before. The new era is approaching very fast and as time goes, we see that everything is getting automated to enhance the performance of an individual and increase efficiency. Internet has brought a new age in the human civilization by providing connectivity to anyone anytime and anywhere. The advancements which have come in the technology of sensors, processors and silicon chips in general have allowed theses chips to be sold in a cheaper rate. Hence giving us the opportunity to integrate them in our day-to-day life. If anyone wants to expand the services of internet then Internet of Things can be said as the expansion of internet services [1]. Today's internet is now expanding towards Internet of Things (IoT).

A. Internet-of-Things

The internet where the existing network of internet to the computer systems will connect to the real-world objects or things. Things may include any objects, home appliances, devices, vehicles, etc. And when these things connect to the internet in specific infrastructure via standard protocols then the whole system is said to be Internet of Things (IOT) [1-4].

B. Smart Home

A smart home is the home or that living environment having technology to allow all the household devices/home appliances to be controlled automatically and can be controlled remotely [8]. In Smart homes user can easily monitor and control all home devices/home appliances through internet. Home appliances connect in

predefined proper network architecture and using standard protocols. Basic idea for Smart Homes using IoT is shown in figure 1 [3].

Using the known concepts of IoT and Smart Home we came up with a new sophisticated smart home which creates user routines and predicts power consumption from the data received from the various sensors. The system uses data analytics to predict the value of the power consumption that might be consumed in the future and create user routines based on what actions a user takes in the home on a given time. The system keeps in mind the major challenge of security and provides solutions like live video feed of the house, which can be seen via mobile app, an OAuth 2.0 OpenID Connect authorization protocol between client (device to remotely control and manage the home) and server (Smart Home which is set up to communicate with the internet). The Smart Home can be controlled using a special mobile application which has Amazon Alexa integrated with it or with any recording device inside the home which connects to the personalized Amazon Alexa. Several Alexa skillsets can be personalized to make the whole system more efficient and intelligent. Mobile application homepage is shown in figure 2.

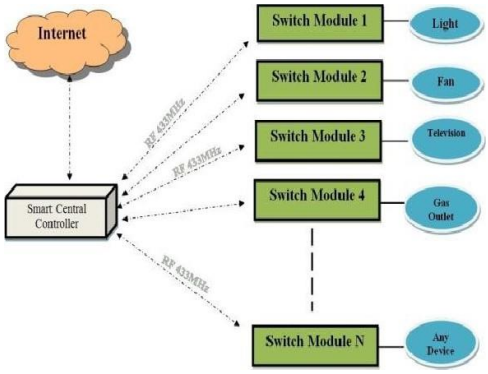

Fig. 1 Basic Idea for Smart Home using IoT [3]

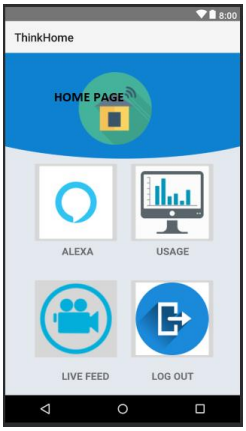

Fig. 2 Home Screen of the application

II. SYSTEM DESIGN

A. System Architecture

The figure 3 shows the flow chart diagram of the ThinkHome system. The entire system is supported on a central server running on the Raspberry Pi and Amazon web service (AWS) Ubuntu 16.0.4 LTS. The Smart Home can be controlled through the phone using the Amazon Alexa Voice Service (AVS). The Data cloud used here is that of MathWorks, PHP Server and Amazon web service. The data cloud communicates with each other through the HTTP commands such as, GET and POST. The mobile application uses the HTTP protocols to fetch data when required.

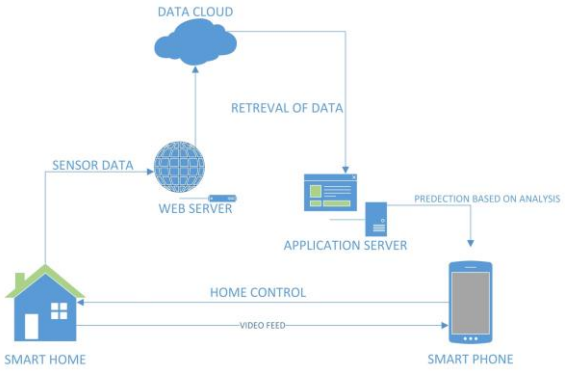

Fig. 3 ThinkHome System Architecture

B. Alexa Voice Service Integration

The figure 4 shows the sequence of activities which happens when an Alexa voice command is given which detects the key word "trigger" and directs to IFTTT server. If an IFTTT activity is triggered it sends an HTTP GET command updating the filed values of the Thing Speak server. The Raspberry Pi when connected to the internet runs a python script which reads the field available in a custom channel in Thing Speak. When the values of the field change it triggers the changes and the home reacts to the new command.

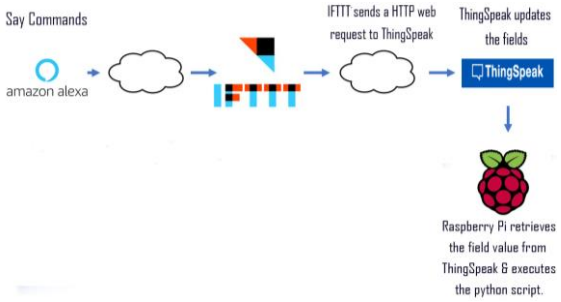

Fig. 4 AVS Integration map

C. Prototype System Block

The figure 5 shows the block diagram of the prototype based on the large-scale system of a Smart Home. We are using Arduino microcontroller and Raspberry Pi microprocessor as the main consoles of the system. The sensors and all the other devices are linked with these two main consoles. The Arduino uses embeded C and Raspberry Pi is using Raspbian OS. The Arduino microcontroller is responsible to remotely control the home and all the devices connected to it. The Raspberry Pi microprocessor is the brain of the smart home which is responsible to accept user prompts and send respective hardware instruction to the Arduino microcontroller to perform the user action.

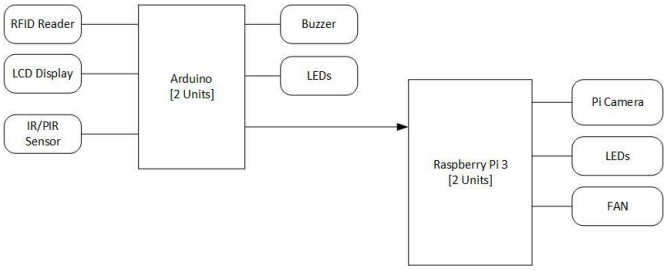

Fig. 5 Porotype block diagram

III.METHODOLOGIES USED

A. Layered Architecture of the IoT-based Smart Home

Layered architecture of the IoT-based Smart Home System is described by Kang Bing et al., in [8]. The smart home system is divided into three layers: application layer, network layer, and sensing layer. Starting from the bottom, sensing layer is responsible for data collection from all the home appliances and it sends data to the middle layer that is network layer. Network layer uses internet for sending data to the upper most application layer which has different applications on different level for different purposes. For data collection and data processing at the sensing layer it used microprocessor SAMSUNG S3C2440A which is a type of ARM microcontroller [8]. To transfer the collected data to the network layer it uses Zigbee module which is based on IEEE 802.15.4 wireless standard [8-9]. Basic architecture is shown in figure 6 [8].

B. Wireless Sensor Network (WSN)

A reconfigurable smart sensor interface device that integrates data collection, data processing, wired and wireless transmission together is already design for industrial Wireless Sensor Network (WSN) in IoT environment using CPLD by Qingping Chi et al., [5]. The interface for Industrial WSN is shown in figure 7 [8].

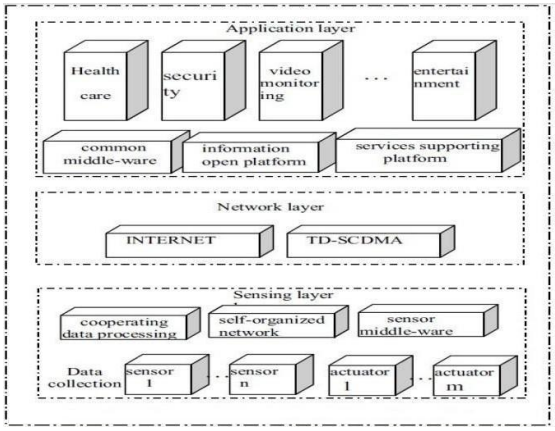

Fig. 6 Layered architecture of the 10T-based Smart Home System [8]

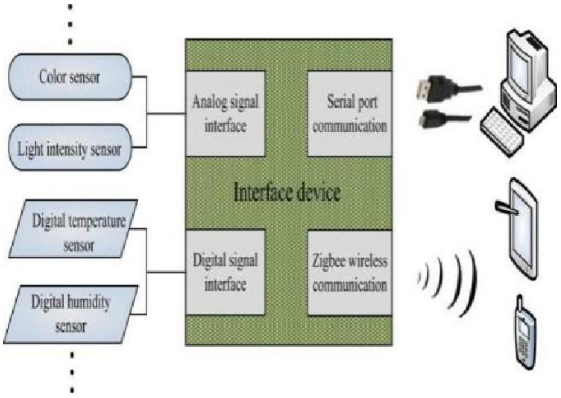

Fig. 7 Reconfigurable Smart Sensor Interface for Industrial WSN [5]

C. Linear Regression using Gradient Descent

In statistics, linear regression is a linear approach to modelling the relationship between a dependent variable and one or more independent variables. Let **X** be the independent variable and **Y** be the dependent variable.

The linear regression analysis uses the mathematical equation, i.e., $y = mx + c$, that describes the line of best fit for the relationship between y (dependent variable) and x (independent variable) [9]. **m** is the slope & **c** is the **y** intercept and the challenge is to determine the values of **m** and **c**, such that the line corresponding to those variables gives the minimum error thus providing with the best fitting line which then can be used for prediction of **Y** on a value of **X**.

1) *Loss Function:* The loss referred here is the error in our predicted value of **m** and **c**. The goal of the loss function is to minimize the error to obtain the most accurate value of **m** and **c**, we will use the mean squared error function to calculate the loss. Figure 8 shows the mean squared error function where y_i is actual value and

$\bar{y_i}$ is the predicted value. We substitute the value of $\bar{y_i}$ with (mx_i + c) and then we square the error and find the mean.

$$E = \frac{1}{n}\sum_{i=0}^{n}(y_i - \bar{y}_i)^2$$

Fig. 8 Mean Squared Error Equation

2) *Gradient Descent Algorithm:* Gradient descent is an optimization algorithm that's used when training a machine learning model. It's based on a convex function and tweaks its parameters iteratively to minimize a given function to its local minimum. A gradient simply measures the change in all weights with regard to the change in error. You can also think of a gradient as the slope of a function. The higher the gradient, the steeper the slope and the faster a model can learn. But if the slope is zero, the model stops learning. In mathematical terms, a gradient is a partial derivative with respect to its inputs.

If we want to apply gradient descent to **m** and **c**, initially we will consider m = 0 and c= 0 and let **L** be the learning rate, this controls how much value of **m** changes with each iteration. We will now calculate partial derivative of the loss function with respect to m and c.

$$D_m = \frac{1}{n}\sum_{i=0}^{n} 2(y_i - (mx_i + c))(-x_i)$$

$$D_m = \frac{-2}{n}\sum_{i=0}^{n} x_i(y_i - \bar{y}_i)$$

Fig. 9 Derivative with respect to m

$$D_c = \frac{-2}{n}\sum_{i=0}^{n}(y_i - \bar{y}_i)$$

Fig. 10 Derivative with respect to c

Now we update the values of m and c using the equation shown in figure 11 and we repeat this process until our loss function is very small value or ideally 0 (which means 0 error or 100% accuracy). The value of **m** and **c** that we are left with now will be the optimum values on which we can perform our linear regression and get the best fit line used to create a predictive model.

$$m = m - L \times D_m$$

$$c = c - L \times D_c$$

Fig. 11 Equation to calculate optimized value of m and c

D. OpenID Connect:

OpenID Connect 1.0 is a simple identity layer on top of the OAuth 2.0 protocol. It allows Clients to verify the identity of the End-User based on the authentication performed by an Authorization Server, as well as to obtain basic profile information about the End-User in an interoperable and REST-like manner [7].

OpenID Connect allows clients of all types, including Web-based, mobile, and JavaScript clients, to request and receive information about authenticated sessions and end-users. The specification suite is extensible, allowing participants to use optional features such as encryption of identity data, discovery of OpenID Providers, and session management, when it makes sense for them [7].

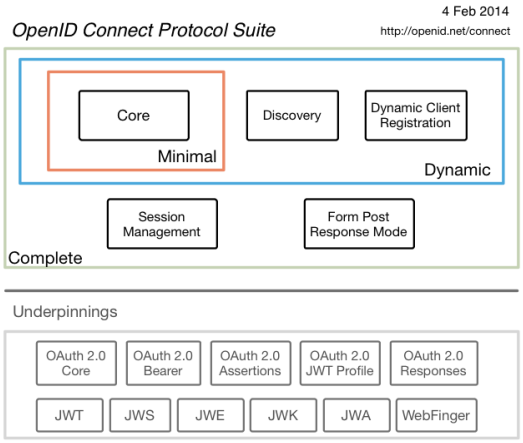

Fig. 12 OpenID Connect Protocol Suite [7]

IV. PROBLEMS AND CHALLENGES

There are many key challenges in the Smart Home system. With rapid growth of IoT applications, problems like managing and controlling these various applications pose a high threat. The whole system could not be more comfortable, secure if these increasing applications not controlled efficiently and conveniently [3]. The server is left exposed posing a grave security threat since no special method for authentication is used. An attacker can get easy access to victims' home and could corrupt the Smart Home system leading to loss of privacy and massive breakdown of infrastructure. It also comes into challenge that how to achieve connectivity at any place any time [4]. For communication towards internet 3G services are used [8]. The functioning of the smart home system in IoT environment should be done in real time. RF identification is used at 433MHz [I] [3] [4]. It may cause the problem of interference.

We will discuss certain problems and challenges faced while making a Smart Home and how our system is designed to provide solutions for the same:

- Identification: The challenge is to have unique identification for each device that is integrated with the Smart Home. We propose to solve this problem by adding each device in database and generating unique ID mapping for each device using a randomizer.
- Authentication & Privacy: Keeping user data confidential is very important. We propose to solve this problem using a login access list in cloud. To access the Smart Home Functionalities the users must create an account in our application and only then will they be allowed to access the Smart Home. We also propose the use of OpenID Connect to secure HTTP calls between server and client.
- Security: The system must intercept security threats and take appropriate action to deal with it. To deal with this we propose the use of RIFD cards to access home and a face recognition software which will be responsible to authenticate the user. To intercept house break-ins, we propose to have motion detection sensors and CCTV cameras which can be used to monitor the home even when far away.
- Integration: The main challenge is to have applications which are IoT ready so that we can integrate them to the ecosystem. We propose the solution to this by replication our system design which makes the electrical systems smarter rather than making device smarter. Our proposed system does not demand IoT capable applications but focuses on how to make the electrical main line of the house smarter which in turn can interact with the devices.
- Network Self-Organization: Network structure should be crated in such a what that the devices have the capability to re structure and the ability to self-organize themselves.

V. CONCLUSIONS

Internet of Things has various applications and use cases in different areas, Smart Home System being one of them which has been developed. This paper presents the system design and the various methodologies used for a Smart Home and how it can be enhanced by integrating with already available virtual assistance like Amazon Alexa, monitor and manage the power consumption and have daily user routines created making daily chores easier and smarter. This paper also presents the problems and challenges what would come and provides solutions of some of the known problems of IoT such as the security of the system.

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