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Internet of Things in Cloud

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Abstract: The daily lives are more integrated into networks of wireless sensors and smart surroundings for its health, safety and comfort applications. From smart homes to smart office environments, these wireless sensor networks are used to increase the individuals comfort. Internet of things relies on networks to create an omnipotent sensor based network and device control measures based on IP addressing. Cloud computing when integrated with the internet of things can provide added ultra-technical value. Aggregating various resources and tailoring it into things like semantics paves way for the evolution of cloud of things (COD). Arduino, the open source programmable microcontroller device that can sense and interact with the environment with wired and wireless connectivity to the internet plays a major role in this study. This intelligent system communicates directly with the appliances which are IP assigned to the cloud database such that the user accounts have the accurate control over the registered appliances and totally reduces human intervention. In this proposed study, researchers put forward, the methods for the implementation of a low cost internet of things on cloud using Arduino. Also, this study proposes a Smart Energy Management System (SEMs), that will make use of internet of things with >1 type of wireless communication technique based on the requirement to collect energy information from the users and communicate it to the cloud server and saves energy efficiently.

Key words: Internet of things, wireless networks, cloud, arduino, India

INTRODUCTION

Researchers are in the world where smart objects surround us everywhere in the lives and those intelligent objects should be completely controllable and independent of user profiles and time and space span instead of only being invented and interconnected. Internet of Things (IoT), paves way for the future vision of the internet that connects physical things from currencies to vehicles through a network where it takes an active part in exchanging information about themselves and their surrounding and gives immediate access to information about the physical world and the objects in it, leading to innovative services and increase in the efficiency and productivity.

The demand for electricity has grown drastically and is expected to grow even more. The existing power grids are centralized and unidirectional in nature. They lack equipment to monitor the usage profile, loss prone areas etc. on a real time basis (Li *et al*., 2011). Smart grids are power-data communications network that enable collection and analysis of near-real time data (Gao *et al*., 2012). Major functionalities that are to be accomplished by the smart energy management system are demand side management, monitoring and controlling consumer appliances, economic benefits to both supplier and consumers (Benzi *et al*., 2011; Koutitas, 2012).

A smart energy management system can provide optimized energy usage by means of smart equipment or devices, smart appliances and smart buildings. Demand response program also allows the user to earn financial incentive during peak sessions by reducing energy consumption. This not only lowers expenditure for the users but also avoids the additional infrastructure to cope up with the rising energy demands in the place of interest. This smart energy management system will provide real time energy monitoring and usage information that helps in real time energy management and electricity price forecasting. Data information is communicated using standard data access techniques combined with web interfaces. This enhances user's profits and save their time by pre-determined energy consumption details which will be closely related to the actual usage and also enables remote on-off mechanism of the appliances under the complete control of the user. The system can also provide intelligent control by installing intelligent nodes that will sense human presence, temperature, humidity and luminosity based on which the smart appliances can be controlled (Li, 2013).

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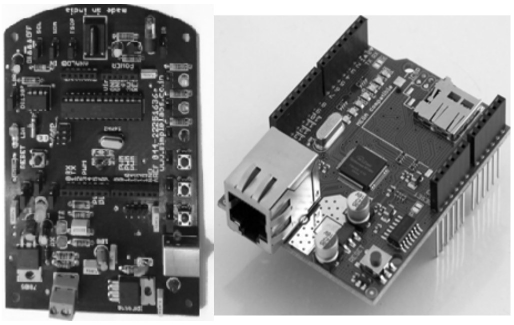

Fig. 1: Arduino microcontroller and arduino ethernet shield

This study studies the state-of-the-art of IoT and presents the key technological drivers, potential applications, challenges and future research areas in the domain of IoT. With data booming in internet, the masses of data being generated by humans has almost become unmanageable. All the storage devices that were in use seemed out-dated and insufficient. With the advent of cloud computing, investment in hardware and software could be eliminated and end users can exploit the power of data centre and thereby enjoy unlimited data storage anywhere at any time via internet. Whereas internet of things makes all objects interconnected and aids the mechanisation of mechanizations.

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors and other actuators. The microcontroller on the board is programmed using the arduino programming language (based on wiring) and the arduino development environment (based on processing). Arduino projects can be stand-alone or they can communicate with software running on a computer (Fig. 1).

In this study, researchers put forward the methods for the implementation of internet of things in cloud using arduino to support future smart applications which are based on standard file system interface.

LITERATURE SURVEY

There are still issues to be addressed in IoT. Firstly, there is no standard regulation or platform on which IoT has been built upon and this prevents its globalization process. Secondly, most of the research works focused on RFID and WSN based object and loses the scope of IoT. Thirdly, everybody thinks IoT is just interconnecting and tracking all objects. Researchers are in the world where smart objects follow us in every corner around the lives and those intelligent objects should be completely controllable and independent of user profiles and time and space span instead of only being, invented and interconnected.

Many countries have already taken initiatives for smart grid and their main focus is on client intelligent power usage (Li *et al*., 2011). Automatic Meter Reading (AMR) plays a major role in client intelligent power usage. They help in collecting real time information, load forecasting and to take decision about power pricing according to time. This helps to achieve orderly power usage. But currently, AMR can only perform one way communication and they lack in facilities that can enable two-way communication. Initially PLC (Power Line Communication) technique was proposed for AMR communication. But, it had serious stability and reliability problems as communication signal cannot be transmitted through transformer and the low voltage signal will be attenuated by the environment seriously. In recent years, Zigbee based communication for smart meters were studied and proposed. But, they lack interoperability and global accessibility whereas Wi-Fi based networks overcome these disadvantages and has better inbuilt security, as it is based on IP network technology.

Household smart energy consumption is gaining large awareness as it contributes to a major part for national energy balance (Benzi *et al*., 2011). Smart meters are the new equipment's that help in achieving the above requirement. But, mostly their interface with the utility is well established whereas its interface with the household is underestimated and thus, does not have a proper well defined technique. The electronic meters are largely being deployed and they are primarily used for meter reading, billing and energy supply administration and thus serving only the utility side. Digital communication techniques are flexible and thus the capabilities of electronic meters can be extended in a way to serve the end user or consumer and hence, can provide uses like power consumption in home display, automatic load management to stay within the maximum demand limit and various other demand response programs. A two-way communication is necessary for the following reasons: Consumer should be aware about how much energy they are using in order to reduce or adapt to the consumption according to the needs; to regulate energy usage according to time of price for the day and balance the energy demand. So, a consumer should be aware of his consumption and the time at which energy is being used. This information can be provided to the consumer only if two-way communication is provided.

Wireless connection between the meter and the house (Li *et al*., 2011). The wired connection in the mentioned method is replaced using a wireless connection and here it is proposed to be the 802.15.4 standard for the lower layers and upper layer is the Zigbee standard which operates at 2.4 GHz ISM band. One limitation is distance as only a distance of 10 m can be guaranteed. Disadvantage physical interference and security. Now these issues are being addressed by the manufacturers of the radio devices.

Web based communication between the meter and the house (Gao *et al*., 2012). Meter data is accessed through TCP/IP and through a gateway installed at home. This gateway uses a cabled or Wi-Fi connection to interface with the internet. In this case, the meter becomes an addressable node with an IP address. Disadvantage; the frequency of energy usage update is not sufficient for implementing many real time services, such as energy monitoring and load management.

SYSTEM DESIGN

Software design is an iterative process through which requirements are translated into a blueprint or constructing the software (Pressman, 2009). In the designs of the project data abstraction, data refinement and data analysis are properly handled. The designs will also depict the entire idea of the software which is proposed in this study, briefing the addressing of the data, functional and behavioural domains in terms of an implementation perspective. The various designs of this project, such as the:

- DFD diagram
- Structure chart
- Use case diagram
- Sequence diagram
- Architecture diagram are explained

Diagram data flow diagram: It helps us to view how the data can be processed over the application. The basic flow is represented by the DFD level 0 (Fig. 2). More detailed flows can be represented in higher version of a DFD level diagram. The detailed DFD level 1 diagram is shown in Fig. 3. The square boxes are represented as input or output, the circle represents process (function) and the edge tells us the flow of the application. For example user enters his/her details in the GUI, the sign in function takes login details as input and replies login status.

Sequence diagram: Sequence diagram is an interaction diagram that emphasizes the time ordering of the messages (Ashton, 2009). Figure 4 explains how the

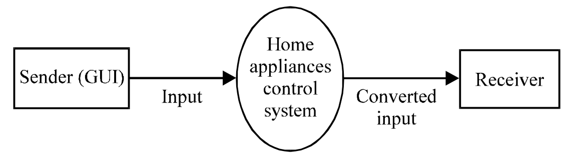

Fig. 2: DFD Level 0 (context level diagram)

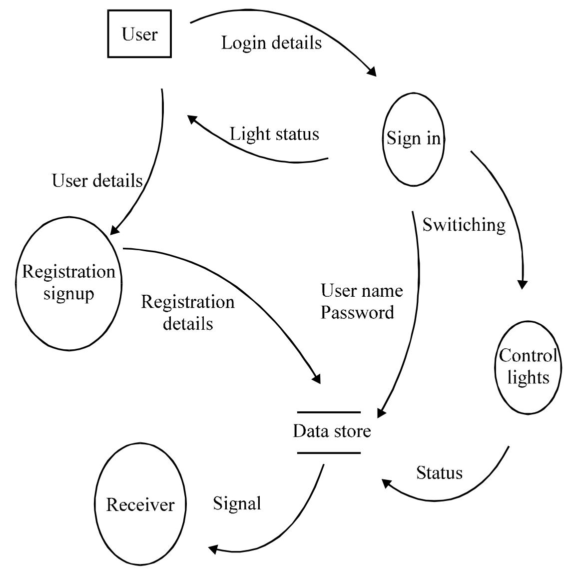

Fig. 3: DFD Level 1

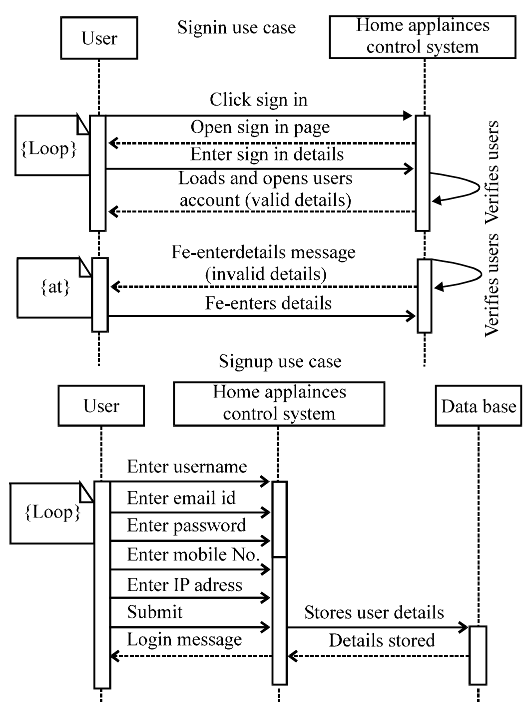

Fig. 4: Sequence diagram signin use case and sequence diagram signup use case

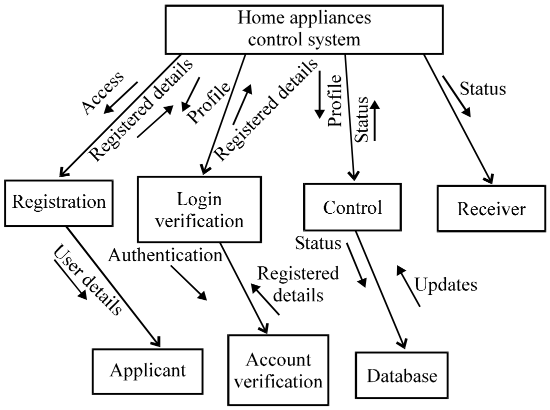

Fig. 5: Structure chart

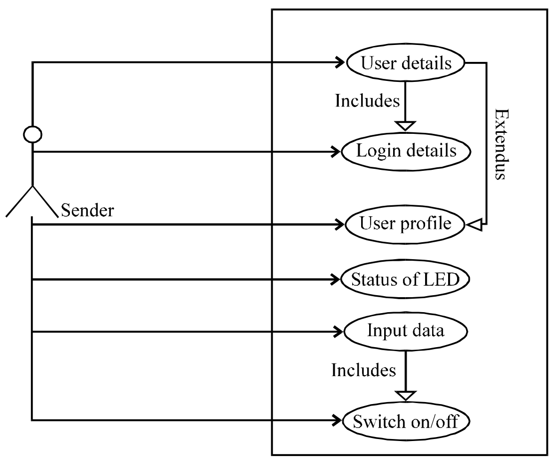

Fig. 6: Use case diagram

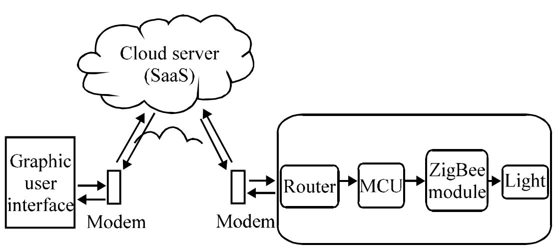

Fig. 7: Architecture diagram

user signin and signup process works out in the application, respectively. The user, home appliance system and the receiver configuration details are shown in Fig. 4, depicts the way in which application controlling the light is demonstrated using sequence messages.

Structure chart: A Structure Chart (SC) in software engineering and organizational theory, is a chart which shows the breakdown of a system to its lowest manageable levels (Martin and McClure, 1988). Home appliances control system is broken down into smaller units such as registration, login verification, control and receiver. These details are depicted in Fig. 5.

Use case diagram: The user interaction with the system focusing on what the system is doing specifying the functionality of the system rather than representing the details of the individual features of the system. The interaction between the sender and the different functionalities of the system from the user login details to the updating of the switch on/off event is given in Fig. 6.

Architecture diagram: The entire architecture of the system from the GUI, cloud server and to the microcontroller setup is depicted in the architecture diagram (Fig. 7). This represents the high level structure of the proposed software system with the sender and the receiver part and a cloud as an intermediate medium between them are separately indicated.

EXPERIMENTAL SETUP

The project is divided into 3 phase of implementation. The first phase is the Graphic User Interface (GUI). Second, the receiver side, the hardware setup of the project and the third is the connectivity which links the application and the hardware setup.

The graphic user interface: The graphic user interface is made by a set of webpages which has the control over the hardware in the receiver side (Fig. 8). The webpages are created using HTML, the styles and formatting of the webpages are done using CSS, the validation of the sign in and sign up form are done using JavaScript with predefined jQuery. The data handling is done using python 2.6.4 and the Google app engine is used as the data store.

The sender side of the system is a web based graphic user interface. The graphic user interface is hosted as a software in the cloud, i.e., software as a service. Also, researchers are using Google app engine which offers the ability to build and host web applications on Google's infrastructure. The receiver side of the system is a circuit set up wherein the system is connected to a router; router is connected to an arduino ethernet shield which is then connected to ZigBee. The input from the sender flows through the app engine server and is then sent to a router. The router on receiving the packet will examine the IP address from the packet header and will check the table which has details of ports and the corresponding IP address (ZigBee and Alliance, 2007). The packet is redirected to

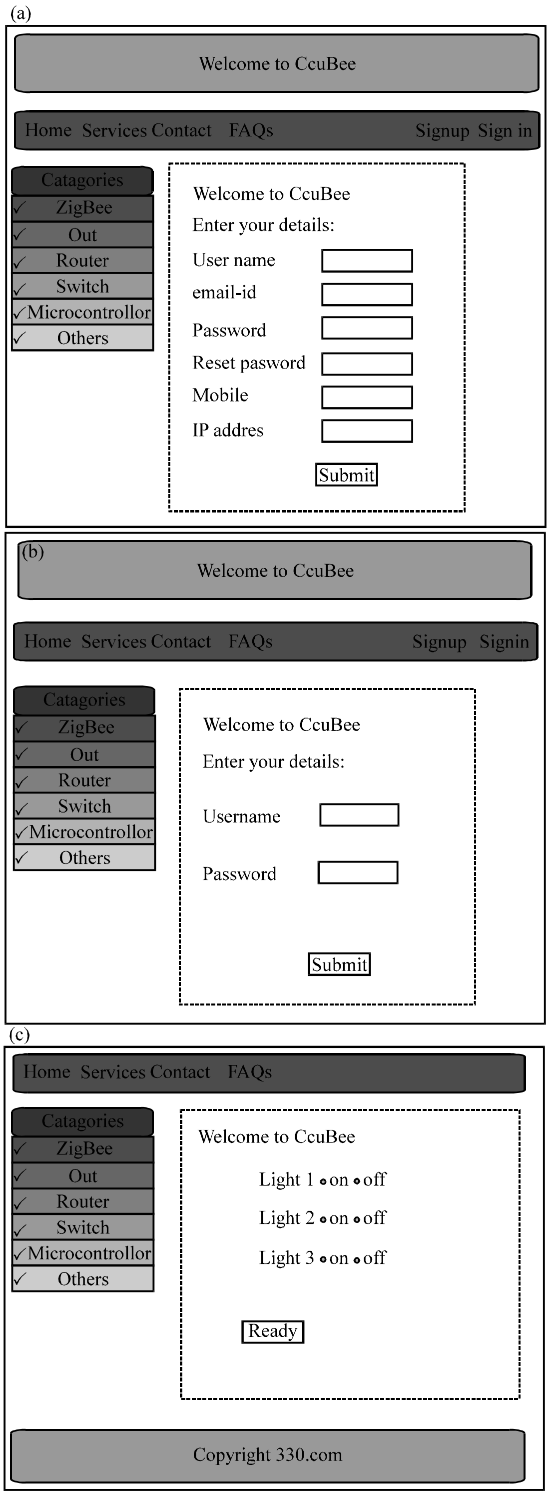

Fig. 8: User interface sign in, signup and profile page

the corresponding ZigBee device. ZigBee device will examine the input and will send the same to the corresponding another ZigBee connected to RF

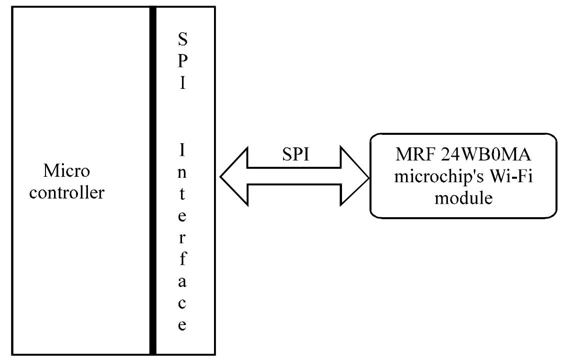

Fig. 9: Microcontroller interfacing with MRF 24 WB 0 MA

transceiver. ZigBee then turns on/off the input based on the input given (Ashton, 2009). The index page, containing the home page of the application, provides the information about the application and the sign in and sign up tabs. To access the application, the user has to sign up first. The details of the user entered in the signup form are validated and it is stored in the Google app engine which acts as a data store. To get access to the lights, the user has to signin using the registered details in the data store. Once the user is authenticated, they will be redirected to the profile page where the user is given access to the appliances under control. The radio buttons on and off helps to switch on and off the lights in the receiver end.

The hardware setup: The smart system consists of a microcontroller board using atmega 328 family microcontroller, a Wi-Fi module MRF24WB0MA, a RF transceiver-CC2500, power supply for each module, a laptop or system with Wi-Fi capability and that can be configured in either adhoc mode or infrastructure mode (Showndharyaa *et al*., 2013). The Wi-Fi module and microcontroller communicates using the serial peripheral interface or 4-wire interface. Figure 9 shows the block diagram of the microcontroller interfacing with the MRF24 WB0MA module. In the initial stage, smart server was designed and a webserver was initiated. To do this, a unique IP address for the wi-shield, Gateway IP, subnet mask and mode of configuration are the parameters which are configured manually.

Once these parameters are configured the microcontroller with Wi-Fi becomes an addressable server. A user intractable webpage was also designed from which we can provide digital control to the I/O pins. This provides a provision for digital (on/off) control of appliances connected to it. This idea was further extended to control a smart appliance.

In order to do this the microcontroller interfaced with Wi-Fi was connected with an RF transceiver-CC2500. A smart appliance is one which has microcontroller board interfaced with the RF transceiver. The smart cloud server will receive the commands from the user through Wi-Fi and will send to smart appliance via RF transceiver. The smart appliance which is also enabled with RF transceiver receives the control and exercises digital control. The experimental setup is shown in Fig. 1. Initial experiment was carried out in adhoc mode. Later the server was configured in infrastructure mode and researchers were able to provide digital control through the internet.

In the next stage, the smart electricity meter which is interfaced at home or other buildings, labs in case of university are made to interact with the server via ZigBee or RF transceiver. The smart meters gives the following parameters for real time monitoring and control voltage, current, frequency kWh, kVArh, kW, kVAr, power factor. The webpage also has commands to retrieve this information from the energy meter. When the server receives a command to collect the parameters, it will transmit it to the smart meter through the RF transceiver. When the energy meter receives the command, it will transmit the values through the ZigBee interfaced with it. The user can know the present usage and based on that, he can take decision to control the devices. Thus, the consumer can monitor his energy usage and control his appliances through the gateway from anywhere in the world. The central server can use this gateway to send the maximum demand information and a warning notification to the end users.

The connectivity: The connection between the hardware and the software is implemented in this phase. The arduino program written is uploaded in the arduino microcontroller board. The user's input from the application, i.e., on or off status of the light is passed to the arduino board through the router and the ethernet shield. Then, the input is passed to the corresponding ZigBee connected to the RF transceiver (Fig. 9) which will toggle the lights on or off (Shu *et al*., 2013). Storing and retrieving of the data from the cloud will be carried out with the static IP.

INTELLIGENT NODES

The main function of the sensor node is to monitor the environmental conditions based on which energy usage will be optimized. So, the basic parameters to be monitored are temperature, humidity, light and human presence. Human presence has the highest priority (Wi-Fi Alliance, 2012). Only if human beings are present then there will be a necessity for energy usage. For example, if a staff is available in his cabin, then there will be a need to turn on fan or light. But, still there are situations where there is enough light and the temperature but still the fan and lights are turned on. So, the intelligent node will monitor the temperature, humidity and light and only if they are not up to the required levels then the fan and lights will be turned on. Sensors used are:

Table 1: Threshold value for each parameter

Parameters	Threshold
Light	TL = 30 lux
Humidity	TH = 60%
Temperature	TT = 28°C; if TH <60%: TT = 25.5°C; if TH >60%

- Temperature sensor LM35
- Humidity sensor syhs 220
- Light sensor LDR
- PIR sensor

Figure 8 shows the interfacing diagram of sensors with the microcontroller.

Algorithm: Let, P represent the presence or absence of human, L represent the amount of ambient light, T represent ambient temperature and H humidity. Researchers will also define thresholds for each parameter such as TP, TL, TT and TH. As researchers are providing digital on/off control we have these thresholds as reference. Let us also make the following assumptions. P will be either 0 or >0. If temperature is greater than TT, then the digital output will be 1 and 0 if it is lesser. Same way, researchers will assume for other parameters too. So, P = 0; absence of human; P>0; presence of human; L>TL; output = 0; T>TT; output = 1; H>TH; output = 0; L<TL; output = 1; T<TT; output = 0; H<TH; output = 1.

When the daylight is sufficient, there is no need of additional luminance. So, the output must be 0 and hence, no lights will be turned on. When temperature is high, then the fan should be switched on to lower the temperature. Table 1 will give the threshold for each parameter and these are conditions for summer (Schubert, 2006; ASHRAE Standard 55, 2010.

Thus, the intelligent node once initiated will sense continuously and provide real time control thus helping to achieve better energy consumption.

With all these ideas a test bed was setup. It consists of the smart appliance or the smart energy management node, gateway or smart server, SEM intelligent node and smart meter. Internal view of the smart appliance is shown in Fig. 10. The smart appliance consists of an intelligent circuit that can control the appliances, according to the command it receives. To make the appliance intelligent

Fig. 10: Snapshots of the experimental setup in the test bed

a microcontroller is added to each node and is connected with an RF transceiver. The loads are connected to the I/O pins of microcontroller. They cannot be connected directly as the output current of the microcontroller pin is only 20 mA and it will not be sufficient to drive AC load. So, a relay circuit is also designed. The test bed consisting of smart appliance, smart server and the SEM intelligent sensor node was deployed at the university and it is shown in Fig. 10, the setup of SEM intelligent sensor node.

The test bed was tested with various communication techniques like bluetooth, Wi-Fi, wired LAN networks and the load was managed according to the real time energy profiling. Control was established via internet and also locally. The output of the intelligent node was later used to control the smart appliances based on the environmental conditions.

EXTENDED COMMERCIAL APPLICATIONS FROM IOT

Recent survey on internet of things has predicted that there could be up to 16 billion connected devices by the year 2020 with an average of nearly 6 devices for every person on the planet. The IoT has yet to become a mass-market proposition. All of the technologies and tools required to create the IoT are available and at suitably low price points but they have yet to be pulled together in a cohesive and user-friendly package and the necessary scale has not been achieved. Arduino is growing beyond much of the expectations and researchers keep on getting moved by such future technologies.

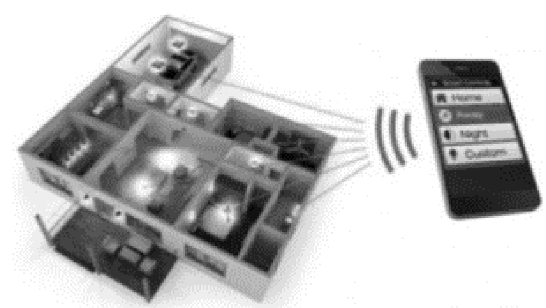

Fig. 11: IOT model of a mobile app controlling a home automation system

Apart from automated lighting for home and office that is the sensors detecting the ambient light, number of people in the room and according switch on and off the lights throughout the house. As this is cloud centric, this could also have a mobile application, through which these can be controlled (Fig. 11).

Smart meters for utilities like water, electricity and LPG cylinders can also detect power cuts which can help prevent pilferage and wastage, especially in places like apartment complexes running generators (Huang *et al*., 2012; Zheng *et al*., 2012). If the generator diesel level is decreasing rapidly without electricity being generated it can be caught in real time. It can, also measure when there is a power cut and report it immediately. For LPG cylinders, it can detect when the cylinder is nearly empty and inform the person to order a new one.

Night lamps with proximity sensors placed in different parts of the house, these lights switch on only when people walk nearby, illuminating only the space required. For example, floor lights from the bedroom to the bathroom switch on as you walk past them automatically and guide you.

Self-parking vehicles and intelligent parking spaces where the intelligent parking space system communicates to you that there are no slots available or may tell you that there are 2 slots available and show you which ones exactly. Once you reach there, the car automatically parks it.

GPS-based people/object/asset tracking useful for keeping things within a perimeter, locating lost objects, security management of valuables in transit, etc. Tags or wrist watch with a chip that communicates the location of children, pets, older patients with memory problems, etc. and sends the information in real time directly to your phone. It can also be used to track objects like keys, jewellery, ATM cash, BPO cabs, etc.

Pollution monitoring to monitor and report pollution levels in a city so that people with asthma can avoid those places.

Smart communication systems can help vehicles talk to each other and also to the traffic signals. In such a system, cars can automatically pass important information to other cars around them. For example, it could say that there is a traffic jam ahead and ask other cars behind it to reverse. Or cars could pass on information to other cars in front of them that an ambulance is coming and ask them to make way. It could, also communicate with traffic signals which can then change to allow the ambulance through, stay green longer for roads where traffic inflow is larger, etc. Driving habits of your own car and surrounding cars are tracked and reported to police, insurance agencies, etc. Insurance companies can maintain your driving history like a credit history for finances. If you are driving well and there are few complaints on your car from other cars that have observed you then your premium comes down for auto insurance. In hit-and-run cases, the damaged car or nearby cars can automatically capture the identity of the car that committed the accident and report it to the police.

Real time medical status scanning to monitor signals like EEG, heart rate/BP, asthma, temperature, etc., of a person and report any abnormalities, so that corrective action can be taken immediately.

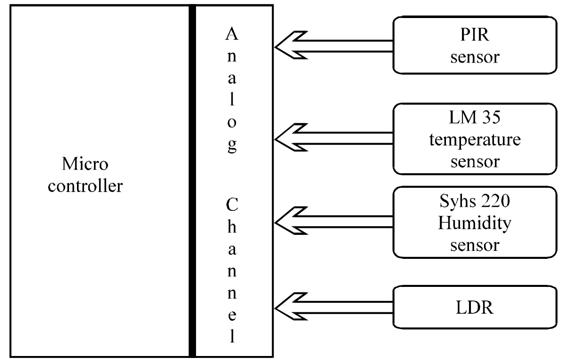

Fig. 12: Sensors interfacing with micro controller

- Retina based automatic teller machines
- Weather forecasting

Automation of agriculture and fisheries. These are sensitive to temperature, humidity, timing and regularity of feeding, etc. Using sensors, any discrepancies can be auto-corrected in real time (Fig. 12). Self-controlled flying device such as Quad copters and drone-like devices can autonomously find their way to a given destination, make a delivery and return to base.

Maintaining a cold chain for vaccines and food packages in relief or rescue operations and meat storage helps in temperature monitoring and management where transported vaccination is stored in deep freeze but when it gets close to final location, the temperature is reduced and the vaccination is brought up to a temperature that is ready for use by a patient.

Water level tracking in tanks at homes and apartment complexes can be used to track the water levels in the sump tank, as well as the overhead tank. This can be used to switch on/off the water pump to ensure that all taps have water available continuously. Information about the water levels are also sent to the mobile phone, so that apartment complex maintenance officers can order extra water tankers when necessary without waiting for water to get over. Track water consumption and report if abnormal (maybe due to leak or open tap), sound alarm on sump overflow. Integrate sump and bore well system. Measure rate of filling of the tank which helps to detect bore well yield, dry running (& health) of motor.

Automatic dog feeder for Indian market will enable the user to preload food into the device and it will release right quantities of food into pet dishes at automatic intervals or when you command it to from your mobile phone. This device is being designed for Indian market and hence should be capable of serving wet food such as milk and rice, etc., in addition to dry food like pedigree.

Surveillance system/burglar alert where provision to connect analog/digital sensors like magnetic reed switches, PIR motion sensors and pressure sensors is established. Output relays to connect hooters, alarm systems. GSM/GPRS connectivity for emergency SMS, also making it easy to configure using SMS or facebook post on friend's wall in case of emergency. Additionally can be used to control and monitor water tank level etc.

Personal fitness trackers, wearable ID band on wrist, are also available which detect proximity to the gym machine. Intelligent gym equipment detects who is using it and how he is using it (how many lifts of 5 kg dumbbell did Ram did on which day and time). All this event data goes to a backend processing system where health analytics are done.

Multi-purpose smart hand gloves, keyboard for laptop, keypad for mobile devices, remote controller for TV, smart control to indoor applications like switching on/off light/fan, etc.

Aggregator and gateway to internet. Connects and uploads all the accumulated data to a cloud. This can control appliances and request info from appliances, defined by a light weight protocol (hand-shake, keep alive, service discovery). Mobile app (android to start with)+webpage access to the cloud and portrays historic data and also can do prediction analysis if possible.

CONCLUSION

This drive for lower-carbon generation technologies, combined with greatly improved efficiency on the demand side has led to a new concept called smart grid management system, enabling consumer interaction in managing energy usage. This brings in the philosophy, concept and technology that enable the internet to the utility and the electric grid, meeting all the user demands and enabling two-way communication of information between the customer and utilities. The entire process history will be stored in the cloud database for managing the energy consumption which will further contribute to the energy balance of the nation. Thus, the idea of implementing a smart energy management system was proposed by incorporating internet of things, cloud computing and a microcontroller is efficient in terms of cost compared with existing technologies used in smart grid. This test bed is tested with various communication technologies, such as Wi-Fi, bluetooth and ethernet and it was able to perform well. The decision algorithm with intelligent server provides better load management and in overall the system provides optimized energy utilization.

RECOMMENDATIONS

In future, energy consumption tests can be carried out in order to measure the efficiency level of the system. This test bed idea can be further extended to control real time loads. The same test bed can be subjected to interference so as to study the acceptable interference levels and security vulnerabilities. Based on the study, a suitable algorithm can be proposed to protect the smart grid against security and interference issues. Whatever has been achieved here is not the end of it. It can take a perspective growth and can be extended further. For example, the same theme can be placed in the society where almost everything can be automated can be developed. Most importantly the same schema can be extended to make the city a less power consuming one.

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