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IoT-based Smart Switch Board System for Home Appliances Control

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***Abstract*—Over the years, IoT has gained importance in a way to create 'smart objects' with embedded sensing, actuation, computation, communication capabilities to share information and provide value-added services to an end user. Smart Home technology with IoT is greatly on the rise as it promises to provide comfort living with optimal use of resources in a secured environment. This paper proposes the design and implementation of smart switch board control system for local/remote switch control of home appliances/devices in a room through the dedicated web-based control application accessible over the internet. Using the standard Ethernet integrated with embedded controller and programmable interactive switch board, the system allows the authentic remote user to control the ON/OFF switch operation of room devices such as lights, fans, heater, cooler, mobile charger etc. as well as speed-control of fan through the graphically designed web-application with unique IP address. The current status of the room appliances is also refreshed on the remote panel following the bi-directional communication over the network. The continuous real-time performance of the system prototype, tested under different operational modes using web-application on home server or mobile phone, was satisfactory and reliable. The system, was able to accurately and timely operate and update status of multiple devices remotely with no false indication and negligible time lag of 2-3s. Compatible with existing home devices, the proposed system is a low cost IoT version of room switch board that enhances the comfort level of occupants to remotely operate the home appliances and thus save electricity.**

***Index Terms*— IoT, embedded network device, remote appliance control, smart switch, board, mobile application for appliance control.**

I. INTRODUCTION

In this modern age of Internet of Things (IoT), many applications in the areas such as healthcare, smart vehicles and transportation system, smart education, smart home/building, factory floor or smart grid have sprung up to provide connectivity of real-world physical system to internet [1, 2]. Extending the well-established and understood principles of Internet to connect objects is the key approach to create web/internet of things [3, 4]. IoT is rapidly evolving due to the convergence of Information and Communication (ICT) and Operational technologies [5]. Basically, IoT is a network of physical objects that consists of sensors, software and electronics which have the ability to communicate with each other as well as with users [5, 6]. One of the most important components of IoT is a 'Smart Object'- an item equipped with a form of sensor or actuator, a tiny microprocessor, a communication device, and a power source that give the smart object the ability to interact

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with the physical world [6]. Such objects support computationally assisted connectivity among physical items, wireless communication, and with interaction between the virtual and the physical world [6, 7]. Among the applications of IoT in the urban context, the concept of Smart home/building is gradually gaining ground that promises to improve the quality of lifestyle of the residents by the use of Information and Communications Technology [5, 8]. In general, smart home comprises of many sophisticated networked devices which are programmed to suit the user needs [9].

A. Survey

A sample of the survey indicates that different level of home automation systems have come up to make the lives of the occupants more secured, safe, comfortable, easy-out along with better management of utility resources [4,10]. Some authors have proposed wireless monitoring of environment and displaying information on different client units such as android phones [1] by integrating mobile services and GSM with home automation technologies [11,12]. Others have discussed the use of embedded webserver, single-chip implementation of the Ethernet networking standard [4], in the place of PC-based server for home automation system. This allows direct connection of appliances to the control-communication unit instead of server and allows user interaction through the web browser [13]. Many intelligent devices with embedded webserver using TCP/IP and HTML web page have been designed to enhance the comfort living and energy-efficient operations of devices [3,4,14,15]. Use of virtual instrumentation technology to design versatile user interfaces and hardware implementation for smart home applications have also been exploited [16]. Many authors have discussed different indoor network architecture and protocols for home automation such as multimedia based broadband access using residential gateway [17], integration of digital TV and home networks [18-19], designing middle layer for network devices in home networks [20] and use of established PAN, Bluetooth technology for home networks [21]. Recently emerged, the short range and low power wireless sensor network standards such as ZigBee with WLAN [22], proprietary Z-wave [23] have been exploited for home automation networks for different applications such as indoor air pollution monitoring [24], ambient condition monitoring and integration with TCP/IP protocol, IoT-based systems for home appliance control have come up for home appliance control [25, 26].

Some authors discussed the integration of smart grid with home networks using machine to machine communication protocols for home energy management [27, 28]. Apart from design and development of smart home system, performance evaluation of smart devices has also been discussed [6, 29], comparison among existing PAN, WAN and new communication standards was made [30, 31] and suitability of different protocols for specific home application presented [6]. Apart from using wireless network, the idea to use RS-485 simple serial communication standard was proposed as a solution for building/home automation systems [32]. Further, the smart home technology is also gaining importance for assisted living and making life earlier for handicapped persons [33]. Some reputed companies have launched their home automation systems based upon standard and/or proprietary communication solutions [34, 35]. Many of the home appliances such as lights, fans, thermostat, security locks, door bells etc. are becoming sophisticated and energy efficient [10, 36]. According to one of the research report, smart home technology is greatly on the rise because of the awareness among customers for value-added services in a home. The need for safe and secure home is the strongest drive to buy smart home services [37] followed by comfort and energy efficiency home systems [38]. Manufacturer specific devices, proprietary communication protocols and incompatibility of devices with various protocols is the basic hindrance to fully realization of the concept of IoT in home automation [38].

B. Work Overview

Looking into the various aspects of smart home networks and home automation system as discussed in the literature, this paper concentrates on one of the very important and less talked about concepts of smart switch board control system for home devices/ appliances. Generally, in a traditional non/semi-automatic homes many of the devices such as lights, fans, air-conditioners, heaters, and other appliances such as ovens, geysers, semiautomatic refrigeration system etc. are user operated through switch boards. Switch board in homes generally consist of mechanical switches and sockets to manually switch ON/OFF the distributed electrical devices and/or to plug-in the appliance. In order to extend the capability of traditional switch board to remote monitoring and control, this project has been implemented. The goal is to create ‘smart switch board object’ suitable to drive the home devices through push-button switches operated locally and accessible over the internet using dedicated web-application. The system uses the popular IoT based technology of embedded web-server (Ethernet LAN) and web-application to facilitate two-way communication with switch board appliances and

remote user. Moreover, the mobile user can also operate the system through smart phone connected to the Internet.

II. Proposed System Hardware And Software Design

The proposed remote home appliance control system is implemented by leveraging the existing Ethernet communication and smart mobile phone technologies with an embedded switch board controller and electrical appliances**.** Fig.1(a) and (b) show the block diagram and software design model of proposed system**.** The system hardware consists of important components such as smart switchboard, switch board controller, relay actuator, network communication module and home server. All the hardware components are interfaced to the switch board controller to communicate with remote client/user over Ethernet/Wi-Fi network.

The proposed system incorporates the design of smart switch board that overcomes the limitation of traditional switch board for remote operation. Smart switch board is software programmable and supports bidirectional communication with the remote client to operate the switches and read its status on a remote internet based user interface. It is easy to use and install, has intuitive user interface and high level of compatibility with the existing electrical wiring system and home appliances. The basic components of smart switch board are programmable push buttons as mechanical switches [39] to operate the device/s, LEDs (light emitting diodes) to view the status (ON/OFF) of the devices connected to push button and AC sockets for connecting home appliances such as light, fans, heater, hair-drier, mobile-charger etc. As shown in Fig. 2 all the input and output components of switch board are interfaced to switch board microcontroller, Atmega 328 [40] on Arduino-Uno [41, 42], that controls the switching of home devices/appliances by manual and remote operation. Each push button on switch board connects a particular device to AC mains through the controller and opto-coupler relay actuator [43] unit. The use of opto-coupler relay instead of electromechanical relays supports faster noiseless switching actions, offers more reliability, has longer life and enhances the safety of the unit by providing isolation between the control and power circuit [43]. The control signals from the processor actuates the relays to switch ON/OFF the power to the appliances. Each time a push button is pressed, change of digital input signal state is detected by the controller and in response to this the controller toggles (ON to OFF and vice-versa) the operating state of the device/appliance connected to it. Also, the operational status of the device is indicated on corresponding status LED. For remote switch operation, the physical switchboard is also replicated in embedded software as virtual switchboard through which the user operates the device/s. To support remote communication with the switchboard control unit, the controller is interfaced to Ethernet based LAN communication module (Ethernet Shield) [44] and its IP address is set accordingly to communicate with the LAN switch of the network. The communication device uses Wiznet W5100, Ethernet chip that provides embedded web-server implementation of IEEE networking (IP) stack. Ethernet is one of the most established, reliable and high speed communication network that support multiple mixed topologies of devices for remote access and is widely used in industry and commercial data/computer networks [45].

The system hardware consists of layers of software (Fig. 1(b)) to control and synchronize the operation of the system and execute remote switching operation of devices. The software consists of two layers of program code. One is the embedded control program, implemented on the platform of Arduino IDE [46] that receives

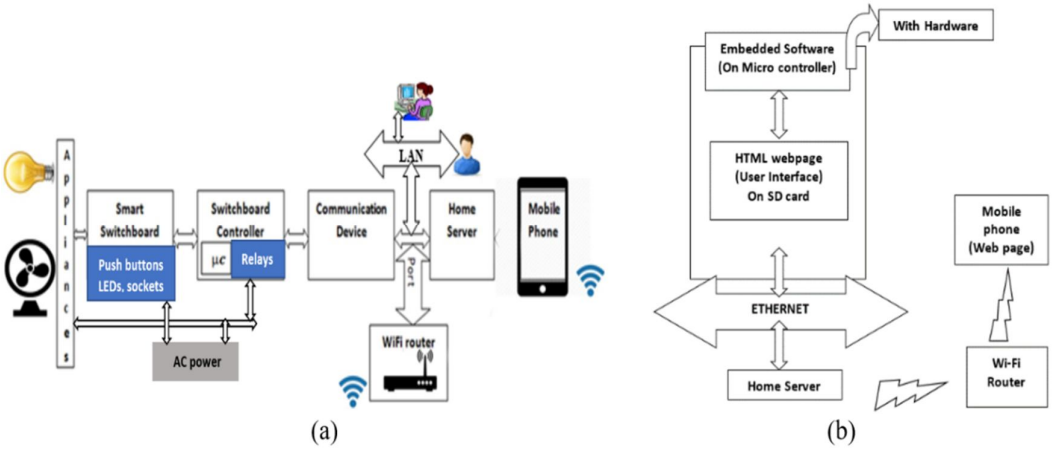

Figure 1. Proposed IoT based smart switch board control system (a) Block diagram (b) Software design model

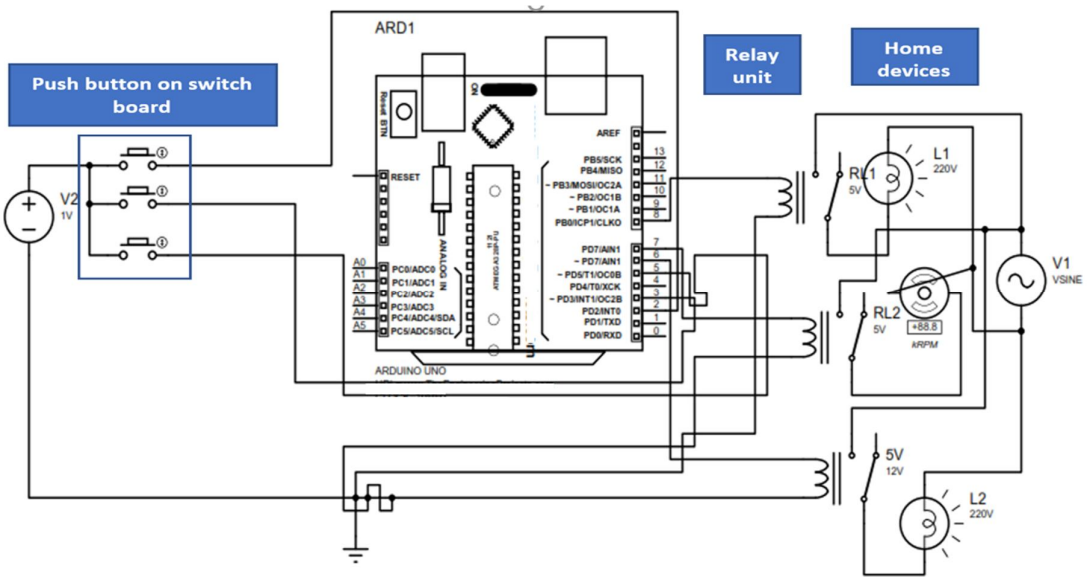

Figure. 2 Circuit diagram to interfacing switch board components and home appliances to smart switch board controller

user switch command from the switch board or through remote panel to activate relay to operate the end device/appliance, changes the status of the LEDs to reflect the operating status of the end device and also updates the status on the device on the remote panel. The second software layer is the web-application program with web-page. The interactive web-page is implemented using HTML [48] and Javascript [49] in Notepad ++ editor to create virtual switch board components such as I/O boxes as graphical icons for buttons to operate the appliances and LEDs to indicate the present status (ON/OFF) of the appliances. HTML page program is stored on the SD card on the Ethernet shield and is accessible on web-browser using its IP address. Any action performed by the user remotely on the web-page is communicated as ajax input command over the LAN network to the Ethernet shield [44]. The received commands at the Ethernet shield is serially forwarded to the microcontroller. These commands are interpreted by the embedded program that in turn initiates the action by activating the actuator to switch ON/OFF the device and change the state of the LED on the switch board and also updates its status on the web-page.

Further, to enhance the security level of the home appliance control, the access to the web-page is password protected along with the personal information of the user thus enabling authentic user to remotely operate the home appliances. The overall system with the general purpose hardware and dedicated software is innovatively designed to make it cost-effective with dual local and remote control facility along with seamless compatibility with the existing home appliance setups and standard home area networks.

III. Experimental Work And Results

Based upon the design as explained in section 2, the system prototype was implemented and was housed in the room for plugging in various appliances as shown in Fig.4. To test the working performance of the system, the system was continuously operated for some days. A few preliminary test results of the system under different operational modes and operating different devices are discussed below:

(i) Operating smart switch board manually: This was a common case where the smart switch board was operated manually by the user to operate bulb/fan /other appliances connected to it in a room. At the click of the push-button, the device (bulb) toggled its state from OFF to ON and simultaneously the current status of the device was indicated on the status LED as shown in Fig. 4. The status of the devices on the switch board was also updated remotely on the web-page of the user interface.

(ii) Operating smart switch board remotely: Fig. 5 shows the operation of home appliance through the remote user interface on home server or through Wi-Fi enabled mobile phone. When the authenticated user opened the web-page of user interface using its IP address, the interface displayed the current status of the appliances connected to switch board. To change the status of the bulb, the user clicked the pushbutton for the same. This signal was communicated in the form of command over the network to the Ethernet shield interfaced to the

controller. In response to the user input, controller initiated action to the actuator to power ON the bulb. Within the time lag of 2-3s, the bulb was actually operated and status of the same was updated on the UI. Additionally, to monitor and control the speed of the fan on smart switch board, another web-application was developed. As shown in Fig. 6, the fan was initially OFF so low, medium and high speed control buttons and LEDs remained at the OFF position. At the click of HIGH button, speed of the fan was remotely changed to maximum, button stse changed to ON and status LED on the switch board was LED on the UI was lit switch borad changed its state . The state of the other buttons remained OFF.

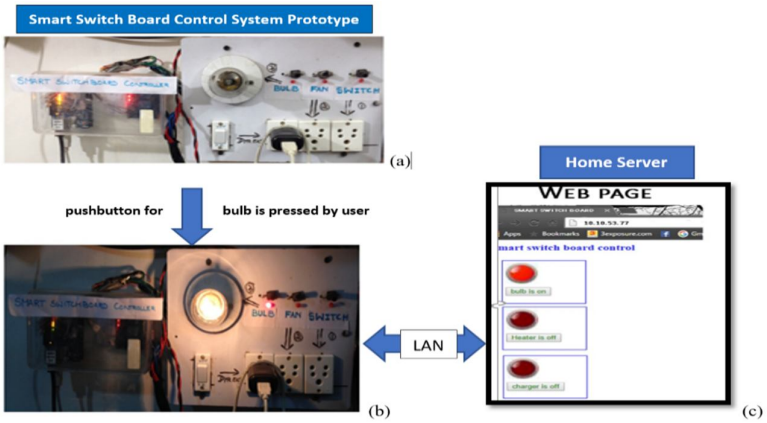

Figure 4. Manual operation of smart switch board (a) Initial state, all devices OFF (b) User pressed pushbutton for bulb, bulb ON, status indicated on LED (c) Current state of bulb updated on web-page of remote user interface

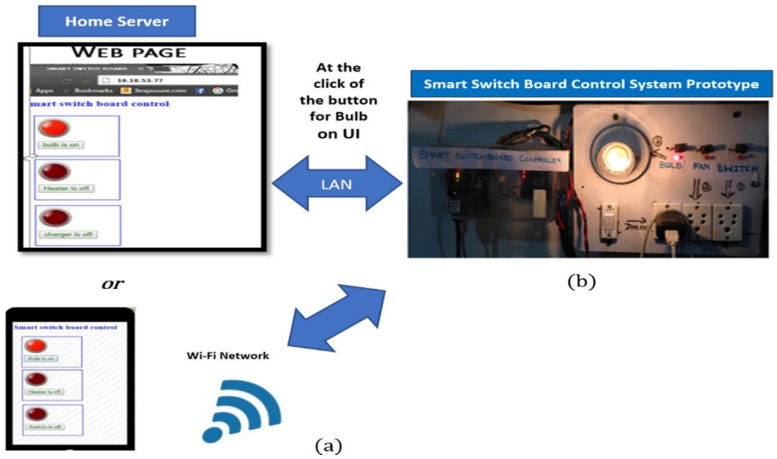

Figure 5. (a) Remote user switches bulb to ON state using web-application UI on home server or smart phone (b) Bulb operated ON and LED activated on the switch board remotely

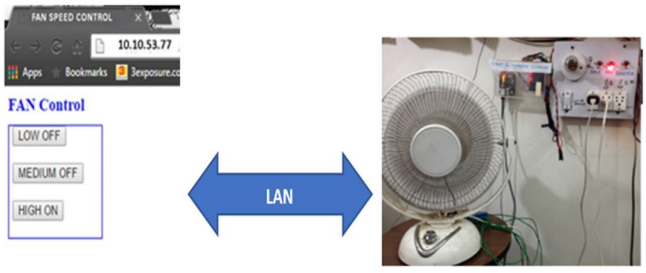

Figure 6. Fan speed control through web-application on mobile phone. Fan switched to high speed and LED for same was activated

IV. CONCLUSIONS

The proposed system that consists of a smart switchboard interfaced to embedded controller and Ethernet communication module has successfully been developed and tested. The system successfully demonstrated the switch control of home devices such as bulb, speed control of fan, ac sockets, ac load etc. locally and/or remotely over the Ethernet or Wi-Fi network. The innovatively designed smart switch board with push buttons, LEDs, AC sockets is compatible with existing home power devices and interfaced to controller. It takes local as well as remote user commands and executes switching of appliances along with indication of the status of each on LEDs. For network access of the system, HTML and JavaScript based interactive web-application with unique IP address is designed as virtual switch board with buttons and LEDs for remote visualization of the status of the devices and/or control the switching operation of the same. Using the IP address, the web-page is conveniently opened by an authenticate user on the remote user terminal such as home server or office PC in the campus LAN or through Wi-Fi enabled mobile phone to visualize the status of the devices and/or control the switching of home devices. This facilitates remote mobile user at any time to interact with the smart switch board and facilitates timely switching ON/OFF the home appliances to enhance ambient temperature/light control for one's comfort and save energy. The system executes reliable, real-time operation over the network with time-lag less than 2-3s. Easily expandable, this switching system is a 'smart object' to create internet of switch control system for home appliances in a cost- effective and east of use manner. Based upon standard LAN protocols, the smart switch board system can become one of the most economic alternatives to home automation with its application in many associated field such as building automation, office automation etc.

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