Integration of Internet Protocol and Embedded System On IoT Device Automation

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Abstract

The integration of Internet Protocol and Embedded Systems can enhance the communication platform. This paper describes the emerging smart technologies based on Internet of Things (IOT) and internet protocols along with embedded systems for monitoring and controlling smart devices with the help of Wi-Fi technology and web applications. The internet protocol (IP) address has been assigned to the things to control and operate the devices via remote network that facilitates the interoperability and end-to-end communication among various devices c,onnected over a network. The HTTP POST and HTTP GET command that supports the RESTful service have been used to ensure the transmission and reception of packets between the IOT Gateway and Cloud Database. The emerging smart technologies based on the Internet of Things (IoT) facilitated features like automation, controllability, interconnectivity, reliability which in turn turn paved the way for a wide range of acceptance amongst the masses. The Internet of Things (IoT) has brought in many new emerging technologies into varoius field like our daily lives, industry, agricultural sector, and many more. The world is experiencing the explosive growth with the advent of Internet of Things (IoT) these years. The potential growth of IoT is enoromous which is evidenced by all the human beings in our day to day life.

I. Introduction

The notion of IoT has greater impact on the lives of the human beings. It has crept in both the domestic as well as business lives of the human kind. In recent years, with the evolution of IoT, the world has witnessed transformation of human life style in many possible ways. Various fields like manufacturing units, inventories, agricultural sectors, etc., are experiencing the huge transformation with the advent of IoT in everyday lives. The concept IoT has been evolving for around two decades and attracts several researchers and academicians due to the estimation of having a greater impact in the emerging world to improve and enhance the lives of the society. The emergency of IoT technology tries to amalgamate everything which is available in this world. IoT is considered a growing technology of everyday life. The biggest challenge in the utilization of IoT is the concept of intercommunication between appliances. The difficulty in the controllability of various devices, clustering different technology, automation of devices of different nature, etc., are some of the challenges which are prevailing in the usage or the integration of IoT into various devices.

When the things are connected over an internet to make them work together by cooperating with one another to facilitate an ideal service as a whole and not the combination of devices that works independently. This idea is much useful in several real-world applications, for instance, smart residence, in which automatic opening and closing of windows based on the switching on and off of an air conditioner or based on the oxygen availability inside the room. Even the public sectors are benefitted using IoT technology in these years. Myriad benefits are experienced everyday by various government and service sectors. IoT enabled applications benefits public sectors in numerous ways like in handling public safety, maintaining and management of resource, city governance, trffic handling and much more.

Many health care benefits are also made possible with the help of IoT devices. Health care benefits like monitoring the patients during their hazardous difficult situation, several hospital administration benefits are made viable to all due to IoT in the field of medicine. IoT benefits can be traced even in th field of agricultural sector as well. Automated irrigation system, crop monitoring technology benefits the farmers of large scale. it simplifies their physical labour. Wireless IoT applications help the livestock management people in updating the status of the cattles. The intergration of automation and IoT in smart watches and fitness trackers also benefits public in monitoring their health. It also further entertains the public through automated music system, smart home technology also enables to set timer and information in our finger tips.

Integration of smart technology at home also results in experiencing myriad benefits. Automation and IoTin various gadjets like smart refrigerators, smart bulbs, smart plugs, smart thermostats, etc., are some of the examples which make things easier in our daily lives. These features help in giving alert messages regarding the stock availability, conservation of energy, etc. The application and usage of IoT technology is limitless. Capability and adjustability of integration of IoT with other device is wide. The relevant information can be obtained, the performance can be monitored, and even it can be controlled from a distance. It is evident that the benefits of IoT is unlimited. The applications of IoT has brought newer promise to the world in bringing immense value to human lives. No longer it remains as a fanciful vision rather it can be experienced by everybody.

The introduction of IoT leads to the transformation of the World into more advanced nature in the field of Information and Communication Technology (ICT). Through IoT various devices are embedded with internet connectivity which enables to share data with other devices used around human environment. The possibility of exchanging data with other system around us made numerous possible things over the web. The interconnection of web is made possible beyond phones and computers due to the initiation of IoT. As a result of initiation of IoT with other house hold and official devices, features like analytical and computing capabilities are made possible. Several devices are involved in implementation of smart technology with the help of IoT. The devices like sensors, actuators, IoT gateway, the cloud, interface, etc., make the implementation of IoT in this era. All these components are tied together with the help of automation for the smooth flow of work. The operational efficiency can be increased with the help of the feature of automation and IoT.

The IoT facilitates the machine to machine and human to machine communication using a standard protocol. Furthermore it enhances workplace safety in all possible ways. The workplace devices which is equipped with sensors will help in detecting failures, maintainance of the working circumstances. Compliance, safety, efficiency, etc can be resolved by IoT and automation. Moreover, this technology helps in overcoming and navigating the longstanding problems with ease. It provides opportunities for new invention in the hands of technology. The global network transformed the ICT with smart device applications [1]. IoT is a self-motivated network that interconnects the physical and virtual objects together [2]. It has been developed from the convergence of wireless technology, embedded micro-chip and micro-electromechanical system and internet for standard configuration and to accomplish

interoperable communication by with the help of embedded systems for the integration of network and things seamlessly [3].

The development of embedded microchip device has been improved which when interconnected with internet gives rise to a concept called “Internet of Things”. The IOT makes use of a set of wireless connectivity like Wi-Fi, Z-Wave, ZigBee, Bluetooth etc. and wireless protocols like HTTP, MQTT, 6LowPAN, CoAP etc. to facilitate better end to end communication among the smart devices and applications [4]. The smart and intelligent devices need scalability for resource constrain, data security, secure packet transmission and power efficiency using RESTful architecture to integrate the cloud services. For a successful connection and interoperability, a developer should understand the complexities and standards of the evolving embedded system based on their IOT device. The embedded system is an electronic device which includes a microcontroller that helps in performing the operations like debugging, user modification or to encode a software which can control the devices.

The monitoring and control of multiple devices using embedded wireless system is going on developing in recent years with the advancement in IOT, as it leads to a new revolution in the field of ICT [5]. The number of smart devices connected to IOT and the smartphones that can access those are exponentially increasing [6]. The Single on Chip (SoC) technology in homes and offices improves the comfort of the lives of people, security and efficient power management. It also enhances the lifestyle of disabled and elderly people who needs additional support for their daily life. Hence, the growth of embedded based IOT is recently accomplishing more attention in the control and monitoring of smart devices and various wireless technologies like Wi-Fi, Bluetooth and RFID are evolving in the automation of such devices. Thus, the wireless technology is going on improving in resource sharing and device to device communication via internet using the embedded systems and internet protocols. This technology gives rise to the automation in the development of smart devices, smart city, smart home, smart agriculture, smart healthcare, smart industry etc. Several researches have been carried out in the development of embedded system based IOT by several industrialists and academicians due to its demand in the connectivity of world with security, comfort, convenience and better quality of lives.

The implementation of intelligent embedded system based IOT for remote data transfer, sensing, controlling and monitoring multiple devices with web applications by the integration of wireless technologies like Wi-Fi, Bluetooth Low Energy (BLE), Z-Waves, ZigBee, RFID and Cellular network [7].

TABLE I: WIRELESS TECHNOLOGY VS. PROTOCOLS

Wireless Technology	Distance (m)	Data Rate	Frequency Band
RFID	5	640 kbps	3 to 30 MHz
BLE	10	1 Mbps	2.4 GHz
ZigBee	10 to 100	250 kbps	2.4 GHz
Z-Wave	100	9.6/40 kbps	908.42 Hz
Wi-Fi	> 100	54 to 600 Mbps	2.4 GHz

Table I shows the comparison of wireless technologies and protocols on the basis of distance, data rate and frequency band. The data sharing and communication between human to things and things to things over a certain distance is based on the transmission and reception through radio waves had been facilitated by the wireless technology. The transmitting and receiving the packets from physical to application layer had been facilitated by the protocols like HTTP, MQTT and CoAP. When the protocols MQTT and CoAP was compared in such a way that the most of the functionalities like level of Quality of Service (QoS), multicast security, congestion control frequent message occurrences and message tenacity, the MQTT was found to have better performance, whereas when the reliability, bandwidth and Round-Trip Time (RTT) were compared, the CoAP was found to have better performance [8].

In comparison with the protocols like CoAP and HTTP, tested with around ten thousand smart devices with a benchmark as Total Cost of Ownership (TCO) along with some technical parameters like energy consumption and data formed while transmitting through applications, CoAP had performed well when compared with HTTP in the sense that the energy consumption was 6x less than that of HTTP PUSH mode. Also, the CoAP protocols generated 62 GB data/month and the HTTP protocol generated 434 GB data/month [9]. These wireless technologies and protocols have been used in several embedded based IOT systems for monitoring and control of various smart devices and enhancing the communication between humans to things and things to things.

Ii. Related Work

A Home automation system based on Bluetooth technology has been implemented in [10]. In this system, an android based smart phone and a web-app is used for the monitoring and control of home appliances like light, fan, television, air conditioner, etc., but interlinking those devices with as Bluetooth sub-controller. The limitation of this system is that the Bluetooth has a low range of connectivity upto 10 m. The access control of Bluetooth makes use of a contention-less MAC with fast transmission and low latency. The Bluetooth architecture adopts Master/Slave concept and has adverting frame and data frame.

The control of home appliances using Wi-Fi with a personal computer which connects the home appliances with the web server database and webpage. The disadvantages of this system include the

high cost and high consumption of energy due to the utilization of high-end personal computer. Another one drawback is that the developed home automation system controls the home appliances only through web application available in the home locality [11].

An embedded system based smart home automation with a Global System for Mobile Communication (GSM) based on web app involves interfacing of devices with the GSM technology and a web server to monitor and control the home appliances and various other devices with the IOT module. The issues faced in this system were, in data transmission, authenticity and SMS/GSM and not video streaming [12].

A ubiquitous home monitoring and control via a smartphone with an android based microweb application to facilitate an innovative communication protocol in the control and monitoring of a home switching system with the help of sensors connected with relays. The major demerit of this system is that, it does not support voice commands for controlling the home appliances [13].

TinyOS is an application specific Operating System (OS) for wireless sensor nodes. The TinyOS has been designed in such a way that it is well suited for sensor nodes with resource constrains like the Mica having flash ROM, 128kb and RAM, 4kb. The TinyOS has a compact architecture that is less than 400 bytes. Due to its compactness, this OS was preferred by several researchers to use it as a basic platform for sensor networks, middleware and several other applications. It includes database, networking, security which are the specific needs for and IOT application on sensor nodes [14]. The same facilities have been found in a sensor networking OS called Contiki, which can be now used as an open-source OS for IOT. It consists of several libraries and middleware related to IOT that can be much helpful in the development of IoT applications. The major challenge in using Contiki is, it facilitates multi-thread support named as protothread, which has very less functionalities and lacks several essential features when compared with the real-time OS [15].

The internet of things can be categorized into semantic-oriented, things-oriented and internet-oriented visions. The internet-oriented paradigm of IOT has been enhanced with the help of semantic-oriented approach, since these two approaches are useful for building a practical and complex IOT application that can be applicable for rich embedded systems. As of now, there were several researches has been carried out for building an IOT software framework that facilitate concrete implementation in the deployment of IOT applications. This system uses CoAP based REST packet transmission [16].

The Near Field Communication (NFC) technology is a short-range wireless communication technology which can transfer data for approximately 20 cm. the NFC consists of a tag which holds only a small quantity of data and those data cannot be modified or deleted. It can be of read-only type data storage like RFID tags used in biometrics, or it can be re-written or modified later by the device [17].

The Low Power Wide Area Network (LPWAN) technology can be applicable for low-power applications and can be used for communication over very long range of around 10 km between the gateway and the end nodes. The data rate of LPWAN is very low of about less that 1 kbps. Major technologies in LPWAN

are LoRaWAN, SigFox and Weightless that operates in sub-GHz bands. The major issue in the use of LPWAN is, the LPWAM in sub-GHz lacks the globally available band [18].

The Z-Wave is a low power consumption MAC protocol specially used in home automation system. It is now also used in several other IoT applications other than home automation. The Z-Wave can cover upto 100 meters, facilitates point to point communication and can be well suited for small message transmission. For media access, the Z-Wave use CSMA/CA along with the small acknowledgement message for reliable transmission. The Z-Wave architecture consists of a Master and Slaves. Here, the Master can control all the slaves connected to it by transmitting the commands and handle the scheduling of the complete network [19].

ZigBee is the most common IoT standard specifically used for medium-range communication like remote controls, smart homes and healthcare. The network topology of ZigBee includes the star topology, peer to peer topology and cluster tree. A coordinator is present in the center of star topology, which is used for controlling the network. The coordinator is available in the root of a tree in cluster tree topology. In peer-to-peer topology, the coordinator can be located at anywhere. There are two stack profiles available in ZigBee standards. They are the ZigBee and the ZigBee Pro. They can facilitate full mesh networking and can function with various applications that allows the implementation with low memory and low processing power. The ZigBee Pro provides several features that includes scalability by assigning stochastic address, security by exchange of symmetric keys and better performance by effective many to one routing factor [20].

In this study, several existing approaches based on the integration of internet protocol and embedded system for device automation via IoT were analyzed for remote monitoring and control of various smart devices and its implementation and development. Hence, in this paper a model of smart automation system using Wi-Fi and android we application has been proposed. The proposed system would facilitate end to end communication, security, interoperability and scalability and various other functions of smart devices over a network.

Iii. Proposed Methodlolgy

The proposed embedded system based IOT communication rely on the configuration of IP address over Wi-Fi (IEEE 802.11 b/g/n) technology. The proposed system consists of various smart devices, Arduino microcontroller, IoT module (ESP8266), wireless router with firewall and external power supply unit. This system also makes use of an android web application and cloud database. The architecture of the proposed system is given in Fig. 1.

A. Smart Devices

The smart devices are the devices that are integrated with the IoT technology to monitor and monitor them wirelessly through a remote network. The smart device— an electronic device— when it is connected to other devices can be operated interactively as well as autonomously. The word smart indicates

intelligence. Smart devices and their usage in every day life is an emerging new trend in the field of technology especially in the era of IoT. The use of smart devices can facilitate ease of access for everyone including the elderly and disabled persons. These smart devices can be used in homes, offices, industries, agriculture, etc. and can be accessed over a range of more than 10 m. The qualities of controllability, interconnection, intelligence, and much more are integrated into various smart devices including households, offices, industries, other sectors like agriculture, production networking, etc. With the emergence of technology, the levels of controllability can be adjusted according to the need of the person. This results in an increased number of users all around the globe, especially in recent days. Thus it can be said that through the Internet of Things (IoT) the entire world is experiencing the era of technology specifically in the hands of the device when they are interconnected with a network of systems. The birth of IoT has paved way for the integration of many smart devices.

B. Embedded System

The smart embedded system refers to the intelligent microcontroller that is used in the development of a system with a firmware coding stored in it. The Arduino (ATmega328) microcontroller consists of 8-bit analog and digital I/O pins, +5V AREF pin, Serial Peripheral Interface communication pins, USB port, interrupt pins for the configuration of changing an interrupt from the rising to falling edges and vice-versa and several other features. These result in integration of technology which aims for enhanced functionality. In this twenty first century IoT has become the most important technologies amongst all. It has made several things possible namely the embedded devices can be connected to various applications of everyday objects which results in smooth flow of communication. Embedded systems are hih demanding because they are customized and programmed according to the needs and the requirements of the users. Smart embedded syatems by acquiring changes to the existing contemporary embedded syatems will result in suitability for real time existence of human life with additional features like cost efficiency and lower power consumption. Embedded device becomes the part and parcel of human life. it can be experienced in our daily life through devices like digitally controlled home alarm, digitially controlled toaster oven, phone which is connected to a web browser, etc, to name a few.

C. Internet of Things Gateway

The self-contained and SOC based ESP8266 module integrated with a TCP/IP protocol stack interlinks the microcontroller with the Wi-Fi network. This chip can be able to host a web application or can deposit all the Wi-Fi networking activities from any other application processor. This module has been designed in such a way that it has some preprogrammed commands that facilitates advanced technologies. These commands are more powerful to handle the on-board processing and storage of various application specific interfaces and sensors connected over General Purpose Input/Output (GPIO). It also supports the minimum upfront development and run-time while loading the programs.

The packets are transmitted via network layer. They are then broken into pieces. Each piece is assigned with a specific name protocol data unit (PDU) and connected with a specific layer. In the top-most layer, a discover packet has been constructed by HTTP client, which is then transmitted by HTTP POST. In layer-4,

the datagram encapsulates the Protocol Data Unit into a segment called TCP/UDP. In layer-3, the IP address of the destination in same subnet sets the IP address of the next hop to destination. In layer-2, Wi-Fi broadcasts the IP address of the next hop, then the destination MAC address of the frame is set to broadcast. Now the PDU has been encapsulated by the device into Ethernet frame for concerned devices. In layer-1, at the same time, the cellular network port transmits the other frame. The devices buffers to transmit the frame in future.

Amalgamation of hardware and software is made possible with the advent of IoT which aims for creating smarter world. IoT has become the basic common platform where integration of other devices are possible inorder to collect and exchange the necessary information. Furthermore, it also acts as a bridge in connecting devices for enabling the features like interaction, collaboration, etc. Several smart devices can be interconnected in real-world, which is stimulated by using the networking tools like packet tracer. The packet tracer supports the representation of several hardware that can be configured by assigning the smart devices with IPv4. For performance analysis like throughput, latency, bandwidth, packet loss rate etc., the NS-3 network simulator is used, as it supports the simulation of IOT. The interoperable protocol used in this system is the RESTful web service with HTTP in the application layer to facilitate client and server communication among the gateway device and the remote user. Along with HTTP, TCP/IP protocol has been used for packet transmission in IOT to cloud database.

D. Software System

The development of system software for the monitor and control of smart devices involves two steps: (1) development of web application in JSON and (2) microcontroller-based firmware microcode in Arduino IDE. In Arduino IDE, the web app and Wi-Fi library < wifi.h > are implemented to allow data transmission and reception. It enables the client server functionality to facilitate better communication among the remote-user and the gateway device. The IOT module and the Gateway device were connected with the cloud database via TCP/IP protocol to provide connectivity for remote users. Whenever the gateway device is switched on, it is enabled for configuration via Wireless Local Area Network (WLAN) with the help of static IP address. The use of static IP address instead of dynamic IP address is to optimize the connection process. Until the gateway device receives any commands from the remote user through a web app, the device would be in the idle state. The Fig. 2 shows the establishment of connection among the embedded system and Wi-Fi module.

The application software runs in the Arduino Uno microcontroller with the help of Wi-Fi chip. The Wi-Fi chip enables the client and server communication through a wireless router. The connection between the gateway device and the remote user with the smart devices has been configured by the wireless router and the Wi-Fi module. The Wi-Fi library helps in receiving the packets from the microcontroller and also creates new packets by passing output message in Java native Language (JNL). The RESTful services for android web applications facilitates the communication between human to human and the human to things connected over a network in JSON format for HTTP POST and HTTP GET requests.

E. Cloud Database

The cloud database and the application layer facilitate the automation, controlling and monitoring of smart devices remotely and enables efficient use of data collected to graphically represent the status of the smart devices via the web application's Graphical User Interface (GUI). Figure 3 shows the overall architecture of the implementation of the proposed system.

Iv. Conclusion

This paper proposed the implementation of smart phone based remote monitoring and control of several smart devices with Wi-Fi technology. If the Wi-Fi connection gets failed, then the cellular networks enable the connectivity among the devices on the basis of RESTful architecture. The proposed system consumes very less power and can be used in various domains like homes, offices, industries, healthcare, agriculture etc. with IOT protocols. The use of HTTP and TCP/IP protocols were encouraged in this paper due to the better performance in connectivity, communication, security and QoS with HHTP POST and HTTP GET commands for with RESTful services for packet transmission between IOT gateway and cloud services.

Declarations

Conflicts of Interest

Authors say there is no conflict of interest

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Informed Consent

All authors have seen the manuscript and approved to submit it to the journal.

Author contributions

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Figures

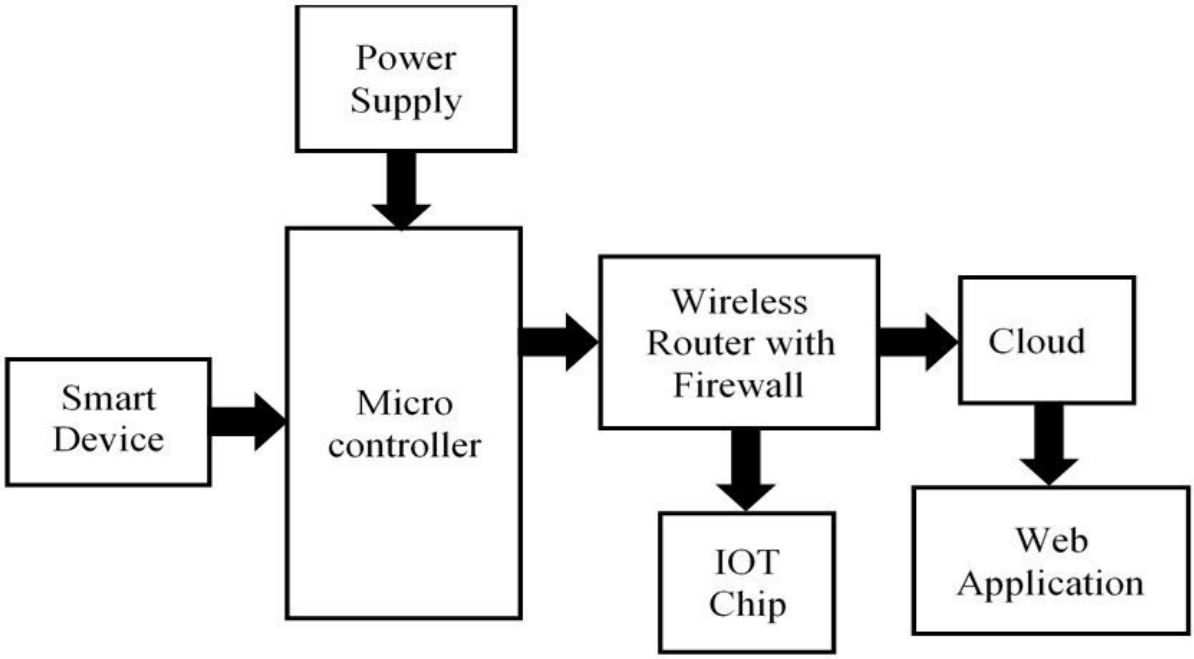

Figure 1

Architecture of proposed methodology.

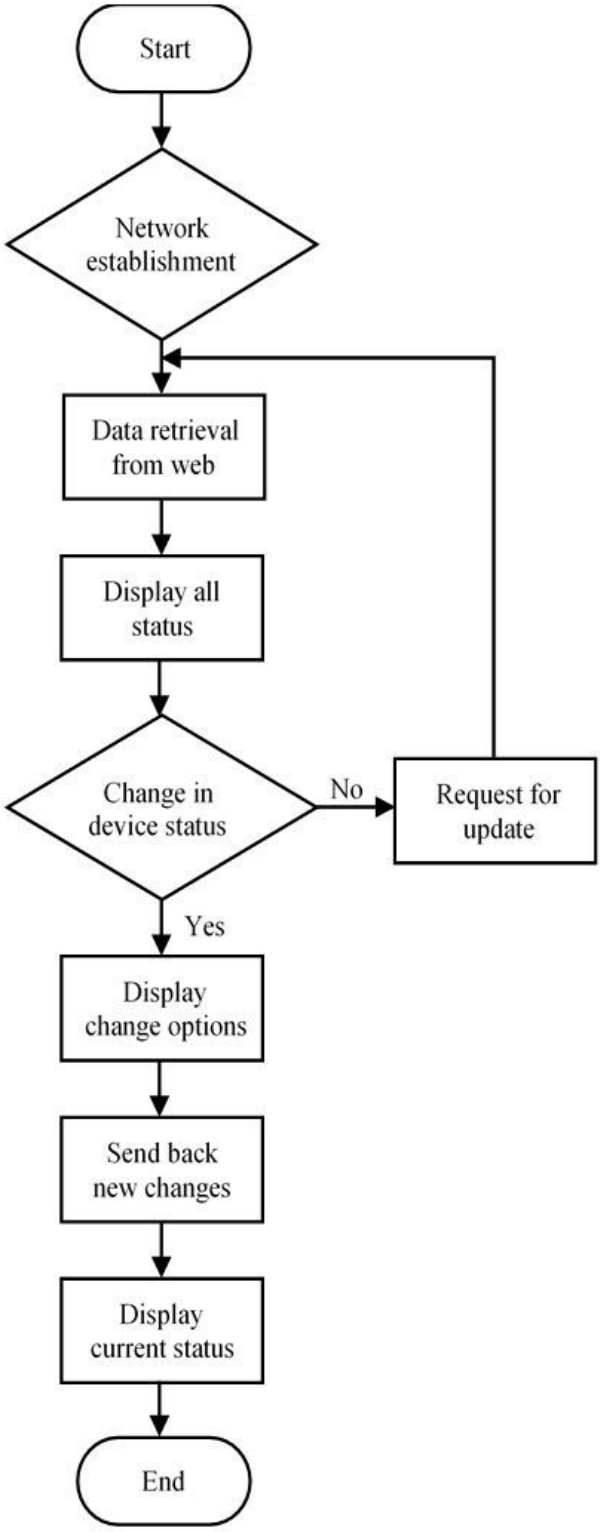

Figure 2

Flow diagram for establishment of connection among the embedded system and Wi-Fi module.

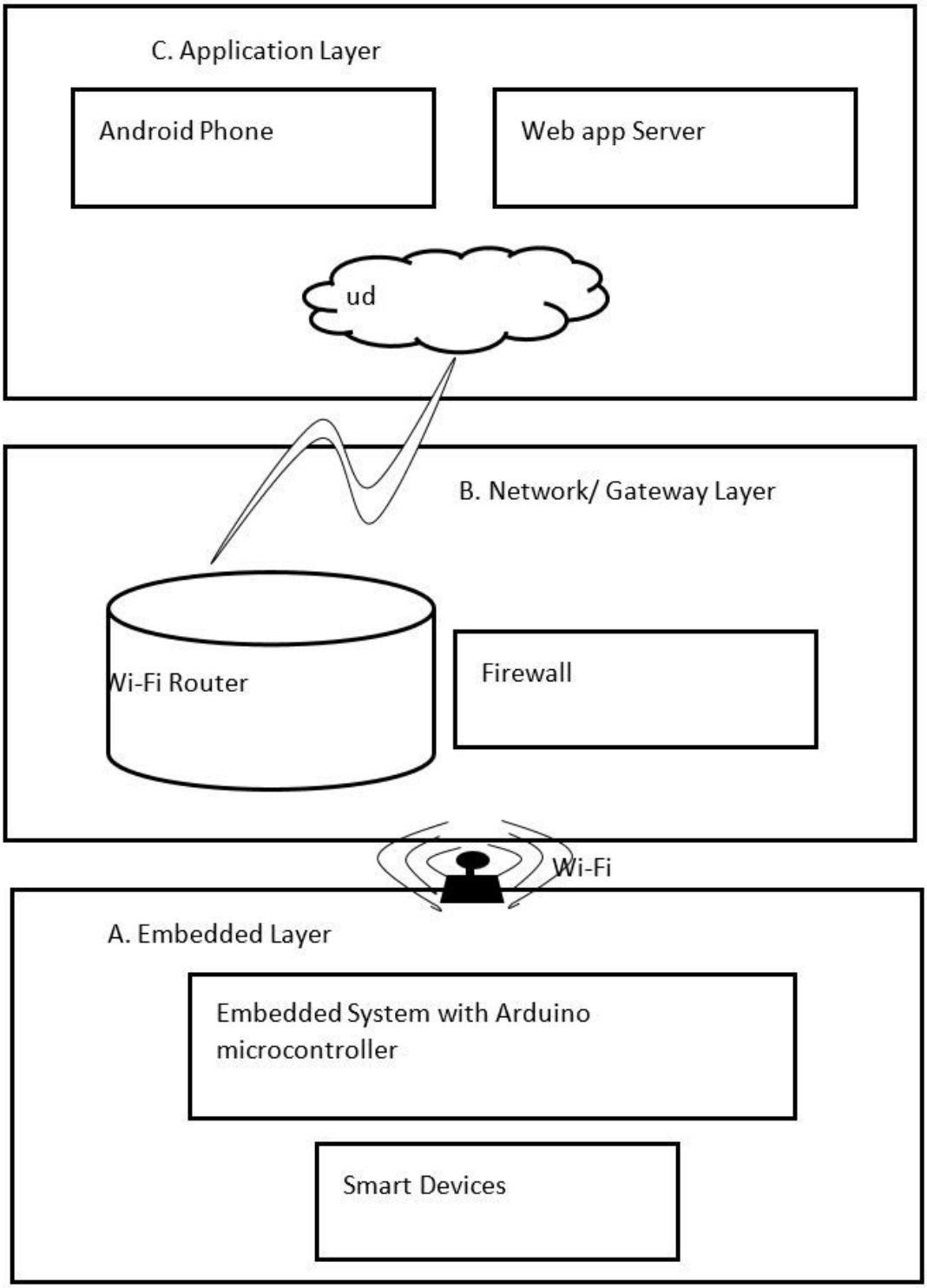

Figure 3

Embedded based IOT Architecture for monitoring and controlling of multiple smart devices.