International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

Technovision-2014: 1st International Conference at SITS, Narhe, Pune on April 5-6, 2014

Wi-Fi based Monitoring and Controlling of Embedded System

Prof. S. V. Shinde
Dept. of Electronics and Telecommunication Engineering
STES's Sinhgad Institute of Technology, Lonavala,
University of Pune, India
Email: shilpavikasshinde@yahoo.co.in

Mr. Pravin Zaware
Dept. of Electronics and Telecommunication Engineering
STES's Sinhgad Institute of Technology, Lonavala,
University of Pune, India
Email: pgzaware10@yahoo.co.in

Abstract **– This paper presents the design and prototype implementation of new Wi-Fi technology based monitoring and controlling the field equipments or machines using Phone, Tablet Laptop or any desktop pc having Wi-Fi utility with IEEE 802.11b, g and n standards. The proposed system is divided into two parts for better implementation; the first part is monitoring the embedded system (field equipments) data and in second part controlling the field equipments. It is very easy, reliable, secure, fast and wireless solution.**

Keywords **– Remote Monitoring and Control Systems, Safety, TCP/IP Layer, Microcontroller.**

I. Introduction

The project mainly focuses on Monitoring and Controlling of multiple field equipments anywhere from within the premises (Department) using Wi-Fi facility.

Wi-Fi works with no physical wired connection between sender and receiver by using radio frequency (RF) technology, a frequency within the electromagnetic spectrum associated with radio wave propagation.

Monitoring is on-line real-time monitoring based on the machine status controlled the field equipments. User does not need to go to near the equipment to operate or monitor. If user wants to operate the equipment he/she will operate from Wi-Fi based device like Phone, Tablet, Laptop or any desktop pc having Wi-Fi utility. Also multiple equipments status and updated data is available to the user. So user gets data easily from the equipments on the Phone, Tablet or Laptop. It is totally wireless communication so no need of any wires complexity.

Fig.1. Main Application Scenario

Sponsored by ELECTROLAB INDIA Pvt. Ltd.

This idea emerges from the significance of fast and cost effective services required at the customer's site. User can operate multiple field equipments at a time, as well as check the data from his place, due to that labor cost is also saved. User can get the data easily on its mobile. No need of any additional front end device.

II. Main Application Scenario

Consider the above shown figure, field equipments (Machine) status is updated on the any Wi-Fi based device like Tablet, desktop, PC, Mobile Phone. Controlling as well as monitoring the machine wirelessly using Wi-Fi based media. When will be Field equipment, power on that time it will broadcasts an ad hoc network with an SSID, MCHP_xxxx Where, xxxx is the last four digits of the MRF24WB0MA RF Transceiver module's MAC address. Connect a client device, such as a laptop, ipod Touch, iphone to the MCHP_xxxx ad hoc network [2].

After connecting the client device, use a standard web browser and the IP address of the Machine. The default IP address is http://169.254.1.1. The some of the web pages from the web server that is running on the machine will be displayed. Web pages displays machine continually updating status using of the three dot circle (Green, Red and Yellow). To control machine 1, 2 and 3 click on the respective circle icon on the web page. In next section we are going discuss about literature review of wireless technology.

III. Literature Review

The literature related to the research topic has been reviewed for last ten years in order to find out work carried out by various researchers.

There are many systems for remote monitoring and control designed as commercial products or experimental research platforms. It is noticed that most of the research carried out belongs to the following categories

a) GSM-SMS protocols using GSM module individually or in combination with internet Technologies.
b) Internet based Monitoring using GPRS modems, Servers, etc. with different approaches.
c) Monitoring using Wireless Sensor Networks.
d) Wireless Monitoring using Bluetooth, Wi-Fi, Zigbee and RF

e) Applications have varied widely like Home Automation, Security Systems, Bio-medical applications, Agriculture, Environment, Reservoir, Bridge health monitoring, etc.

Many Wireless Technologies like RF, Wi-Fi, Bluetooth and Zigbee have been developed and remote monitoring systems using these technologies are popular due to flexibility, low operating charges, etc. Today Wireless Technology used into an increasing number of commercial solutions, aimed at implementing distributed monitoring and control system in a great number of different application areas**.** (Wijetunge et al., 2008) designed a general purpose controlling module designed with the capability of controlling and sensing up to five devices simultaneously. The communication between the controlling module and the remote server is done using *Bluetooth* technology. The server can communicate with many such modules simultaneously. The controller is based on ATMega64 microcontroller and Bluetooth communication TDK Blu2i (Class 1) module which provides a serial interface for data communication. The designed controller was deployed in a home automation application for a selected set of electrical appliances [3]. (Kanma et al., 2003) proposed a home appliance control system over *Bluetooth* with a cellular phone, which enables remote-control, fault-diagnosis and software-update for home appliances through Java applications on a cellular phone. The system consists of home appliances, a cellular phone and Bluetooth communication adapters for the appliances. The communication adapter hardware consists of a 20MHz 16bit CPU, SRAM and a Bluetooth module. The communication adapter board is connected to the home appliance and to the cellular phone through serial ports. The appliances can communicate with the cellular phone control terminal via Bluetooth SPP [4].

(Sung-Nien Yu and Jen-Chieh Cheng, 2005) proposed a wireless patient monitoring system which integrates *Bluetooth* and *WiFi* wireless technologies. The system consists of the mobile unit, which is set up on the patient's side to acquire the patient's physiological signals, and the monitor units, which enable the medical personnel to monitor the patient's status remotely. The mobile unit is based on AT89C51 microprocessor. The digitized vital-sign signals are transmitted to the local monitor unit using a Bluetooth dongle. Four kinds of monitor units, namely, local monitor unit, a control center, mobile devices (personal digital assistant; PDA), and a web page were designed to communicate via the WiFi wireless technology [5].

(Flammini et al., 2007) suggested a novel architecture for environmental tele-monitoring that relies on GSM for sampling point delocalization, while on-field nodes implement local subnets based on the DECT technology. Local subnets contain two major blocks; Acquisition Station (AS) where sensors and actuators are located and Transmitting Module (TM), i.e., the module that handles several measurement stations and sends data to the control center (CC). Each AS acts as a data logger, storing in its internal memory device field data; communications between AS and TM are cyclic (round robin), with a cycle time of about 1–10 min. [6]. (Yunseop Kim et al., 2008) described details of the design and instrumentation of variable rate irrigation, a wireless sensor network, and software for real-time in-field sensing and control of a site-specific precision linear-move irrigation system. Field conditions were site-specifically monitored by six in-field sensor stations distributed across the field based on a soil property map, and periodically sampled and wirelessly transmitted to a base station. [7].

(Bencini et al., 2009) developed state of the art WSN based system for monitoring a series of physiological parameters in the vineyard to prevent plant vine diseases. The different soil moistures in the same field is used to decide the correct amount of water for irrigation; sandy soils have very different behaviour to irrigation in respect to clayey ones; water retention capacity is completely different and measuring it exactly where it is needed can help in controlling the irrigation system and saving water. Monitoring air temperature and humidity in different parts of a vine can help in preventing and fighting plants diseases, reducing the amount of pesticides only when and where they are necessary. Data coming from sensors are stored in a database that can be queried by users everywhere in world, only using a laptop or a PDA: the Smart User Interface also allows to read and to analyze data in an easy way [8].

(Harms et al., 2010) describe the emerging wireless sensor networks (WSN) for autonomous Structural Health monitoring SHM systems for bridges. In Smart Brick Network, the base station and sensor nodes collect data from the onboard and external sensors. The sensor nodes communicate their data from quasi-static sensors, e.g., temperature sensors, strain gauges and seismic detectors to the base station over the ZigBee connection. The base station processes these data and communicates them, along with any alerts generated, to a number of destinations over the GSM/GPRS link provided by the cellular phone infrastructure. [9].

Major strengths:

1. Exhaustive research has been carried out on Internet based Monitoring scheme with various protocols and systems providing detailed description of remote process states to the users.
2. Many systems have been designed and experimented by using GSM-SMS which normally involved the use of GSM modem for carrying sensing and control of devices in the system using message transfer.
3. Numerous systems have been developed using Wireless Sensor Networks which consists of several sensor nodes in proximity and having data transmission and reception capability between nodes and central base station.

Major Weaknesses:
1. Most of systems based on Internet monitoring require higher operational cost based on bandwidth / data speed requirements and hence is justified only in industrial or biomedical applications in developing countries.
2. The development and deployment cost of wireless sensor networks is very high due to need of sensors, radio transceivers, etc spread over large area.
3. It is difficult to upgrade existing conventional control systems with remote control capabilities

IV. Research Objectives & Implementation

Such implementation are quite complex in nature hence for simplifying it, we divided the entire research into sub blocks. With objective as follows,
1. To design low cost intelligent embedded system based remote monitoring and controlling using mobile.
2. To provide flexibility to use any Wi-Fi Front end device model for remote monitoring.

A. Define About Wi-Fi Technology / Wi-Fi Protocol

For a user, Wi-Fi appears to be a wireless form of Ethernet, but it is a fairly different technology. Deriving its working strategy from the OSI model, Wi-Fi uses various data exchange techniques, security measures, network topologies that make it a well strategized wireless network. Since its inception, there have been numerous changes in the 802.11 standard. Let's start with the features that were there when the legacy had just begun.
Wireless LAN uses physical layer and MAC sub-layer (of data link layer) of the OSI model [2]. The physical layer takes care of the wireless data exchange and the MAC layer synchronizes the transmission of data.
There are three sub layers in physical layer:
• Diffused Infrared (DFIR) - Wide angle
• Frequency Hoping Spread Spectrum (FHSS)
• Direct Sequence Spread Spectrum (DSSS)

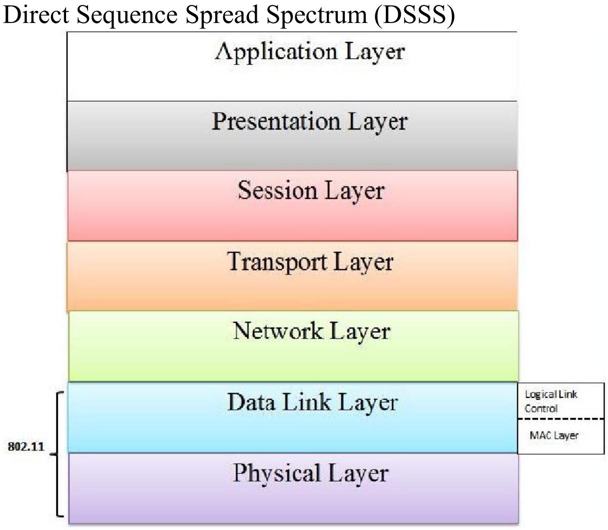


Fig.2. OSI Layered Structure

A comparison of the features of light-based infrared, FHSS and DSSS a wireless network is summarized in the Table-I.

Table I: Comparison between Sub Layers Of Physical Layer

Modulation Type	IR	FHSS	DSSS
Causes Interference	No	Yes	Yes
Can be interfered	No	Yes	Yes
Power consumption	Low	Moderate	Moderate
Coverage	Limited	Broad	Broad
BW(Mbps)	2	2	14

Due to good feature in the DSSS modulation we have select MRF24WBM0A (Transceiver) IC for Wi-Fi Implementation. Some other RF/Analog features of the IC as ISM band 2.400 – 2.484 GHz operation, 14 channels selectable individually, DSSS Modulation, Data Rate – 1000 kbps. The figure 3 shown below is the used to create the frame format at the s/w end. So before going to implement the array, we should understand wireless frame format [2].

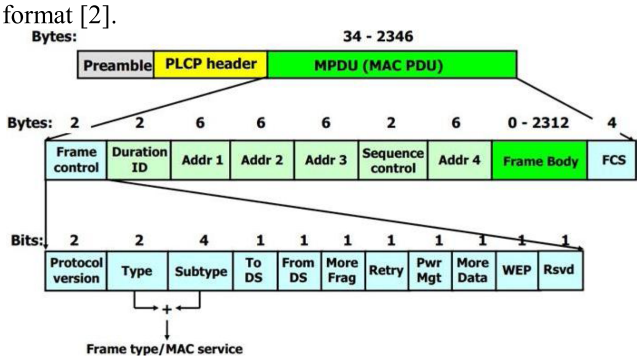


Fig.3. Wi-Fi Frame Format

Preamble: It is first part of the PLCP header and It indicates to the receiver that it is about to receive data. This aids in receiver identifying beginning of signal reception and synchronize frame transmission [2].
Synch: this is 80 bit long sequence implemented by physical layer to choose the destination and synchronize data transmission and reception frequency. Start Frame Delimiter: It is 16 bit digital code which aids the receiver in deciding frame timing.
MAC Header: MAC header details about frame control, duration, addressing, sequence control etc.
Frame Control: It is 16 bit field under which following are specified:
I. The version of the protocol (a, b, g, n etc.)
ii. Type of frame: management (00), data (10) or control (01).
iii. Sub-type of the frame sent.
iv. To DS and From DS indicate signal transmission from BSS to DS and DS to BSS, respectively.

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

v. More Frag: In cases of large message transmission, packet fragmentation takes place.
vi. Retry: Some frames might require re-transmission.
vii. Power Management: This field indicates whether the transmitter would be in active state or power saving state.
Viii. More Data: When a station is in power save mode, a high bit on this field indicates it that more frames are ready to be transmitted to it from AP.
ix. WEP Field: This field indicates the security measures on Frame, and goes high when data is encrypted or encoded.

Frame Duration: A 16 bit long field, field duration is used in multiple ways: (a) to indicate the duration of the frame sent using network allocation vector; (b)carrying the ID of the station that has transmitted the data.

Address fields: The quadruple of address fields along with To DS and From DS field of frame control, form the following combination of data transmission:

Sequence Control Mode: as the name suggests, this field is responsible for managing the sequence with which frames are transmitted and received.

Frame body: contains the information as indicated by the frame type and sub-type field and CRC.

The basic protocols used for this demo work are limited due to the scarcity of memory footprint in microcontroller [14]. Hence the entire TCP/IP stack designed contain following protocols-
1) IP, ARP & ICMP for Network layer.
2) UDP & TCP for Transport layer.
3) TFTP, DNS, DHCP & HTTP for application layer.

There are many readymade stacks available many are open source and many are paid type [16]. This includes all above stuffs only the application layer need to be implemented by users.

Developer can also design the stack by his own but it requires the basic understanding of protocol structure. Next objective is the practical way of Wi-Fi implementation.

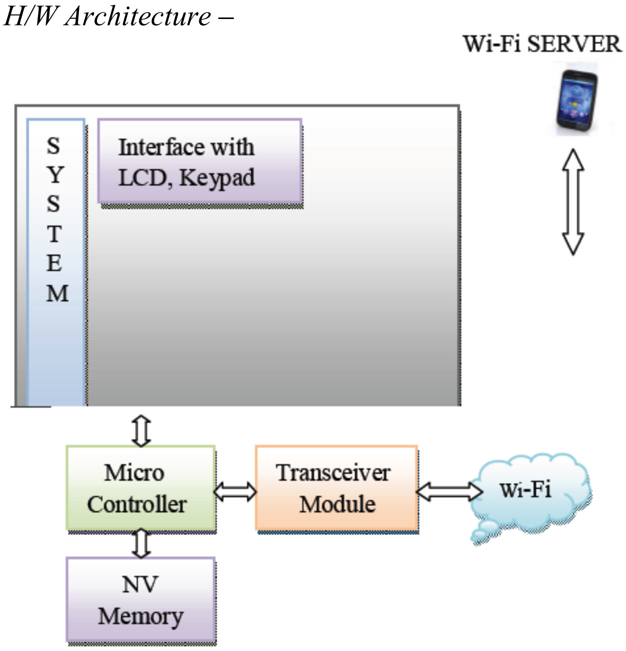
B. Wi-Fi Implementation:

Wi-Fi works with no physical wired connection between sender and receiver by using radio frequency (RF) technology, a frequency within the electromagnetic spectrum associated with radio wave propagation. When an RF current is supplied to an antenna, an electromagnetic field is created that then is able to propagate through space. The cornerstone of any wireless network is an access point (AP).

H/W Descriptions – For project implementation we have used the PIC32 Wi-Fi comm. Demo board [15] to implement the controlling & monitoring operation of embedded devices. Little bit description about demo board as, The board is powered through 2 AAA Lithium batteries. If required, the battery voltage is monitored and boosted by the MCP1642 Synchronous Boost Regulator.

The MRF24WMB0MA RF Transceiver module provides wireless connectivity to the demo board. Host communication is through SPI2 of the PIC processor on the board. The Wi-Fi Comm. Demo Board is designed with a permanently mounted (soldered) PIC32MX695F512H processor with speed 80MHz/105DMIPS, 32-bit MIPS M4k Core, with having 512k Flash(plus 12k boot flash) 128k RAM.
The LED's: LED0, LED1 and LED2 are connected to PORTE and PORTF of the PIC32MX695F512H processor. To ON the LED's, the port pins are set high. Also general purpose I/O pins on the board which can function as an SPI, UART, or I2C port.

H/W Architecture –



CLIENT SIDE SYSTEM/ INSTRUMENT
Fig.4. H/W Architecture

Wi-Fi SERVER

This server at the user side to holds the database of all instruments. Database of server side is containing the physical address of the instrument. All the instrument s have a hard coded physical address (i.e.; MAC ID) programmed by manufacturer at the time of installation of customer site [16].

Secondary Non-Volatile Memory

This is called secondary because it is not at all involved during the system operation. And it is not accessible to the user for storing or retrieving data. This NV-ROM can be any memory starting from EEPROM, SD-card, NANDFLASH, NORFLASH, USB stick etc [16].

Transceiver module

A transceiver is a device that contains a transmitter and a receiver which is both combined and share common circuitry. Transceivers combine a significant amount of the transmitter and receiver handling circuitry. An RF Transceiver utilizes RF modules for high speed data transmission.

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

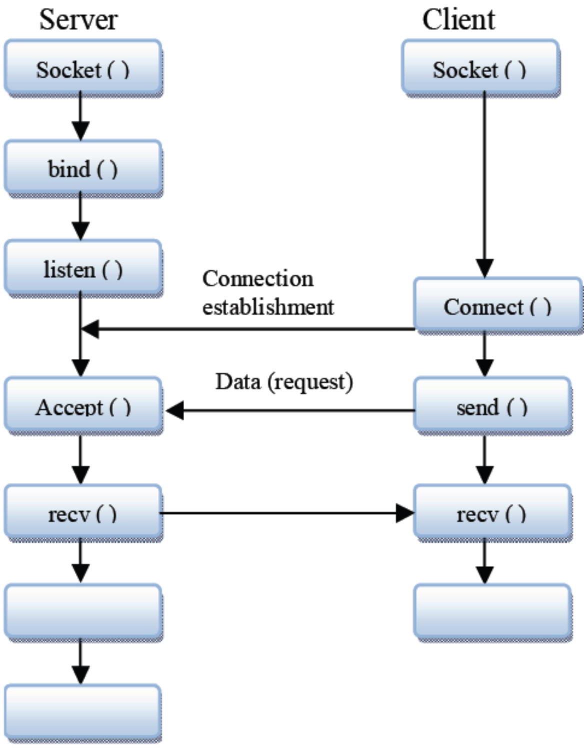
Technovision-2014: 1st International Conference at SITS, Narhe, Pune on April 5-6, 2014

System I/O

System I/O is the input output pin of microcontroller. Here UART, SPI, Sensor related port pins are taken outside on the
pcb connector.

S/W Descriptions –

Client Server model used to implement TCP/IP stack.



Data (reply)

Fig.5. CLIENT-SERVER CONNECTION

CLIENT–SERVER MODE Client-server networks has a machine at the heart of its operations called the server. A server is a machine that provides services over a network by responding to client requests. Server-based networks provide centralised control of the entire network environment. Serverbased networks are easier to scale. The networks operability is dependent on the server.

SERVER MODEL Server is that computer which facilities, sharing of data software and hardware resources on the network. A server is a program running on the remote machine providing service to the clients. When it starts, it opens a door for incoming request for a client, but it never initiates a service until it is requested to do so.

CLIENT MODEL Client is the program running on the local machine requesting service from the server. A client program is finite means it started by user or another application program and terminates when service is complete. Server provides services over a network by responding to client requests. Microchip MPLAB8 [15] is used for s/w development tool to develop code of microchip controller as shown in the below figure.

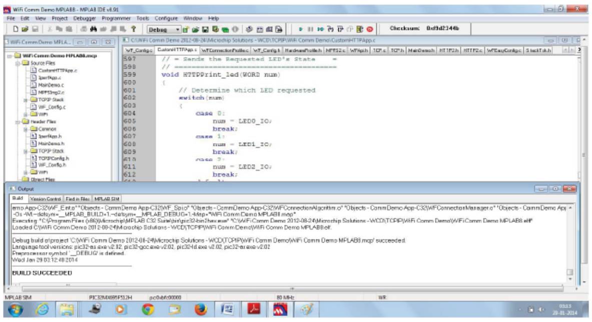


Fig.6. Microchip MPLAB 8 IDE after successful build

Prototype design mainly consist of following parts -

1) For DHCP on LAN side (where AP is DHCP server), set Router to Enable DHCP server. Set Client Lease time to be longer than the typical off time of the station to ensure that the IP address provided doesn't change each time the station is powered up. If an option for Always Broadcast is present for DHCP setup (broadcasts all DHCP responses to all clients), it should be disabled [15].

2) Should typically be enabled so that the AP sends beacon frames containing the SSID. If disabled, ensure that Microchip Stack is set for Active Scanning [15].

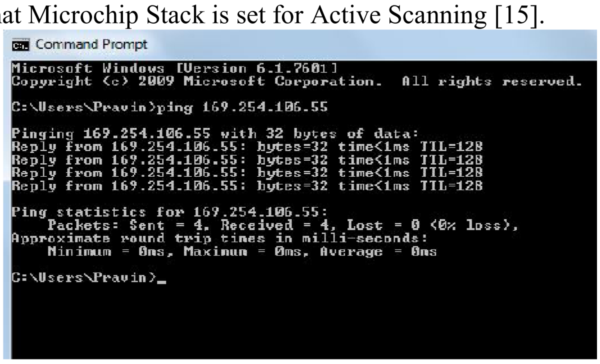


Fig.7. ICMP Result

Using the same arrangement an ICMP (Internet control message protocol) request has been generated by a Laptop on WLAN to the PIC32 board having IP 169.254.106.55. After receiving the request the controller side answer it with ICMP reply. Hence, from the above exercise it is clear that the, an embedded based system can be detected and interacted on a WLAN. Next part is going to discuss about s/w architecture of the Wi-Fi model.

S/W Architecture –

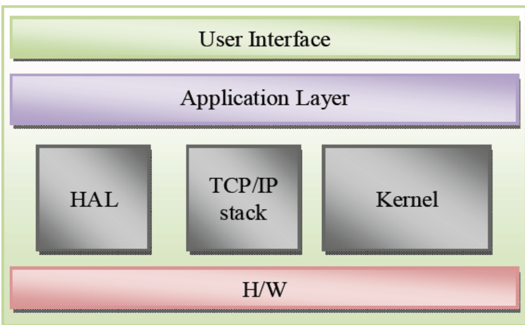


Fig.8. S/W Architecture

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue (4) July, Technovision-2014, ISSN 2249–071X

Technovision-2014: 1st International Conference at SITS, Narhe, Pune on April 5-6, 2014

A. Application Layer

This holds all the function necessary for running the application for which the system/instrument is been designed.

B. HAL

Hardware abstraction layer holds all the device driver, ISR handler routine, data clock access. It allow program to directly access the h/w resources.

C. TCP/IP Stack

This layer include all the necessary code required to implement the internet layers namely Application, Transport and network along with all necessary protocols. Implementation of this part already we are seen in the client server model shown in figure 6.

D. Kernel

This is a real time kernel which is necessary for any complex embedded application to make its operation predictable. There are many embedded RTOS available which also comes with a package of TCP/IP suit.

E. User Interface

This contains the routine which accept i/p from the user and sends the result as an output to the user. This contains all the h/w on which the system will work like sensors, actuators, motors, relays etc.

As shown in the figure 9 is the demo example of controlling and monitoring the status of the Fan using mobile Wi-Fi network.

Connect the client device like any appliances (here Fan) to the server device like Mobile, Tablet or Laptop (here Mobile). Figure 9 shows the proposed system for controlling and monitoring devices using Wi-Fi network. Here we are first tried out the controlling and checking status of the I/O pin of the controller using mobile. In the next implementation we are taken the one pcb board as seen in the below figure to control 230vAC devices using the 5v dc supply of the port pin.PCB board we are using having circuitry to control AC appliances. For the implementation of this demo we are follow architecture as discuss in the earlier part. Initialize core stack layers (MAC, ARP, TCP, UDP) and application modules (HTTP, SNMP, etc.) Initialize Wi-Fi Scan State then establish Wi-Fi connection. Once the connection is established the user can able to connect the device. If device connected successfully then is is in configured state else it is in unconfigured state. When the Wi-Fi module is an unconfigured state (i.e., serving the default MCHP_xxxx SSID in ad hoc mode), the LED (LED 0) will blink twice per second to indicate not configured. After the network is configured, the LED will blink once per second.

Once the server and client connection is successful thenopen web browser and put an IP address as http://169.254.1.1. Then as per shown in figure 10 below web page will open. In the web page continuous data is updated to check status as well user can control the device from the web page which is available either mobile, laptop or Tablet.

Fig.9. Monitoring & controlling the device through mobile using Wi-Fi network

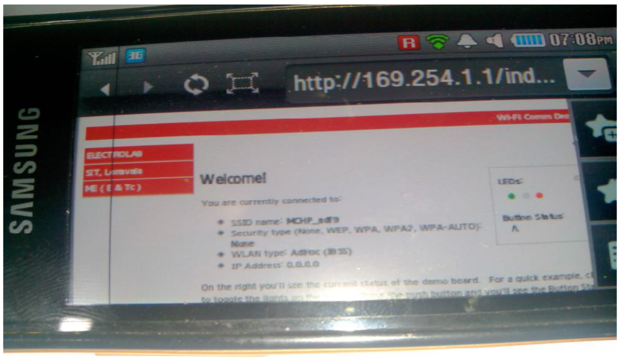


Fig.10. HTTP page open on mobile for monitoring & controlling operation

V. Conclusion & Future Scopes

This paper proposes a low cost, secure, accessible, auto configurable, wireless controlled solution. The approach discussed in the paper is novel and has achieved the target to control field appliances using the Wi-Fi technology to connect system parts, satisfying user needs and requirements.

Wi-Fi technology capable solution has proved to be controlled field equipment data security and is cost-effective as compared to the previously existing systems. Finally, the proposed system is better from the scalability and flexibility point of view than the commercially available field equipment systems. Future scope of this project is firmware upgradation of the embedded devices using Wi-Fi.

Acknowledgment

We would like to thank ELECTROLAB for providing the necessary equipments, Wi-Fi resources for MCFU project implementations. We would also like to thank our guide Prof. S.V. Shinde for innovative ideas and advices.

Mr. Bharat Zaveri, Mrs. Shivani Kamble and R&D team of ELECTROLAB are given valuable inputs on the project, specifically relating to the designing the prototype and networking aspects.

REFERENCES

[1] I. Yamano, K. Takemura, K. Endo, T. Maeno, "Method for Controlling Master-Slave Robots using Switching and elastic Elements", *Proc. of the IEEE International Conference on Robotics and Automation*, May 2002.

[2] TCP/IP Protocol Suite,Behrouz A. Forouzan, Third Edition.

[3] Automation", Master thesis, Viennia univeristy of technlogy, Feb 2007.Wijetunge, S.P.; Wijetunge, U.S.; Peiris, G.R.V.; Aluthgedara, C.S.; Samarasinghe, A.T.L.K.; , "Design and Implementation of a Bluetooth based General Purpose Controlling Module," *Information and Automation for Sustainability, 2008. 4th International Conferenceon,* Dec. 2008.

[4] Kanma, H.; Wakabayashi, N.; Kanazawa, R.; Ito, H.; "Home appliance control system over Bluetooth with a cellular phone," *Consumer Electronics, IEEE Transactions*, Nov. 2003.

[5] Sung-Nien Yu; Jen-Chieh Cheng; , "A Wireless Physiological Signal Monitoring System with Integrated Bluetooth and WiFi Technologies," *Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference* Jan.

[6] Flammini, A.; Marioli, D.; Sisinni, E.; Taroni, A.; "Environmental Telemonitoring: A Flexible GSM-DECT-Based Solution," *Instrumentation and Measurement, IEEE Transactions on*, Oct. 2007.

[7] Yunseop Kim; Evans, R.G.; Iversen, W.M.; , "Remote Sensing and Control of an Irrigation System Using a Distributed Wireless Sensor Network," *Instrumentation and Measurement, IEEE Transactions*, July 2008.

[8] Bencini, L.; Chiti, F.; Collodi, G.; Di Palma, D.; Fantacci, R.; Manes, A.; Manes, G.; , "Agricultural Monitoring Based on Wireless Sensor Network Technology: Real Long Life Deployments for Physiology and Pathogens Control," *Sensor Technologies and Applications, 2009.*

[9] Harms, T.; Sedigh, S.; Bastianini, F., "Structural Health Monitoring of Bridges Using Wireless Sensor Networks," *Instrumentation & Measurement Magazine, IEEE*, December 2010.

[10] Christian Reinisch ,"Wireless Communication in Home and Building".

[11] Wireshark [4] N. Sriskanthan, F. Tan, A. Karande," Bluetooth based home automation".

[12] http://wiki.smarthome.com/index.php?title=Home_Automation

[13] http://www.softpedia.com/progDownload/Iperf-Download-78352.html).

[14] Mr. Suyog A. Wani, Prof. R.P.Chaudhari, "Ethernet enabled digital IO control in embedded system", International Conference on Computing, Electronics and Electrical Technologies [ICCEET].

[15] http://www.microchip.com

[16] Rapid upgradation and remote service station facility for embedded based system, IEEE conference 2013.