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Networked Switching and Polymorphing Control of Electrical Loads with Web and Wireless Sensor Network

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Abstract: **-All the electrical load cannot be controlled using occupancy sensors in buildings/home especially in large public building , this results need for manual control on supervisory manner due to importance of the load or the service requirement. This requires switch box to be fixed on wall/nearby close to the load. To operate the same the person has to travel to the switch box. As the technology keeps growing to serve the mankind the expectation keeps on increasing There is no limit for sophistication .This paper intended to demonstrate web based control for Electrical loads in combination with the wireless sensor network based switch box which provides local mobility to control the load and also the same function can be done through internet . We introduce the wireless sensor network based mobile switch box for sophistication along with embedded web server based control the user can use the wsn switch box or internet to control the electrical load. The load status can be monitored in the web page .We also introduce the concept called polymorphing control by which one mobile switch box designed for one location can be used to control the electrical load in other location .We use open standard embedded controller Arduino mega with Ethernet and xbee nodes. The switch box operates at 3V which more safe and saves the wiring cost partially. Also the power to room completely cut off when the loads were in off condition by fixing the controller outside the room which increases the fire safety. This flexible operation brings energy efficiency.**

Keywords— Internet of things, Wireless sensor networks, digital lighting control, Web based control. WSN based mobile switch box, safety switch box, fire safety, Energy efficiency.

I.INTRODUCTION

Day by day, the demand sophisticated way of operation becoming one of the important requirements of the life. The electrical loads such as lighting and air conditioning etc, in a building can be switched on automatically based on occupancy sensors. If sensor were not installed or in some specific loads have to be switched on only by human only viz. computer, induction stove etc there is need to walk toward the switch box to switch on/off. There is requirement of waiting in front of switch box till completion of the shutdown process viz. shut down time of computer etc or cooling time of the induction stove during shut down process. In case of large public building if the sensor were not installed the user uses the service and leave the place kept the electrical load working .The maintenance person has to visit the switch box to switch off the load otherwise it results wastage of energy . Consider a computer lab the computers are shut down but there is need to switch of the input power for which the person has to visit all the table and does it.

This paper is intends to demonstrate the real time implementation of wireless sensor based switching in with option to control the same through internet in real time using open standard Arduino Ethernet based web server cum controller with zigbee nodes made to function as switch boxes. This wireless switch box provides local mobility and need not to travel to switch off.

The web based control brings the sophistication to control from anywhere. A maintenance person can view the loads which were on/off from web page and he can switch of the loads from internet and whenever the load required to be on the other person/user uses the wireless switch

This brings flexibility of local switching, comfort switching through web either via internet/wifi/LAN. The wireless sensor based switch box facilitates the following (1) only power wiring to the load for many loads with one mobile switch box. (2)This low cost model in addition reduces the switching voltage to less than 5V and these switch boxes do not require any wire between the switch and load. This saves the wiring cost partly. (3)The controller and the load switching relay box can be kept outside the room, whenever the loads are off there is no power inside

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the room unlike the conventional switch box in which there is always 240V .This reduces the fire risk in the room

Related Work

Mobile, blue tooth based home automation was discussed in paper [1]. Zigbee based home automation system was discussed in [2].The integration of DALI system with the wireless sensor network was introduced in [3]. Real time acquisition system using wireless sensor network was discussed in [4]. The WSN used to monitor the real time data and integration to BEMS was discussed in [5]. The web Enabled service oriented architecture is discussed in [6]. Various communications system for building automation is discussed in [7] Wireless technologies for building automation is discussed in [8]. The web services for building automation is discussed in [9] .Wireless Mesh Networks in Intelligent Building Automation Control has been discussed in [10]. The wireless sensor network for multi storey building was discussed in [11]. Various sensor for the smart building to actuate the control are discussed in [12]. Knowledge based intelligent building automation [14] and semantic web based building automation [16] are bringing more intelligence in BAS.

II.THE ZIGBEE FRAME FROMAT and Switch box Design

The design concepts are as follows .The three wsn nodes were used in this work. The three were acting as switch box. One is configured as coordinator which is physically wired to the Arduino act as a fixed switch box cum coordinator. The other two acting as independent mobile switch box. The fig.1a shows the switches and the pins used & fig1b shows the wsn node actual hardware. In order to facilitate the data reception and understanding of the received data all the node configured to send digital input status of their pins along with their address periodically. The coordinator router1 and router 2 periodically send the status. The coordinator receives the data wirelessly among the two nodes in addition it also send its data along with the received data to the Arduino in serial port1.The sample data of the three node are received by the Arduino. The Arduino coding is made identify the packet belongs to which node and segregate the received packet and identifies the pin status from the received data for all the three nodes and they were stored in a array The fig 1b shows the Xbee frame format sent by the xbee node (the wireless switch box) to the gateway node .The start byte is 7E (zero th frame). The length is given in second and the third byte. Frame type is the third byte. The 64-bit source address (Xbee node address) given in 4th to 11th byte. The 16-bit network address is the 12th and 13th byte. The receive option is 14th byte. Number of samples is given in 15th byte. The pins for which digital input option is enabled given in 16th and 17th byte .The analog channel mask is 18th byte. The digital samples are given in byte 19th and 20th byte.

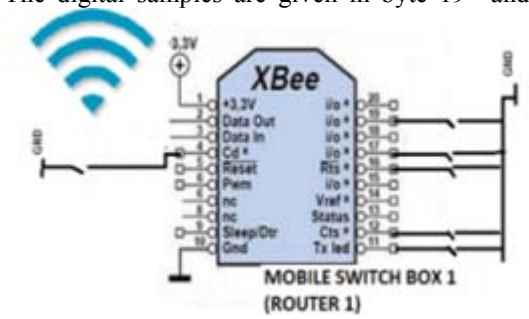

Fig 1a. The Xbee node used as wireless switch box

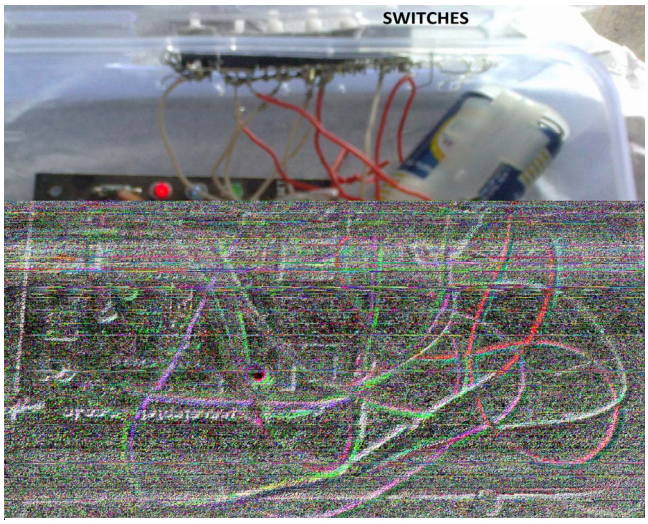

Fig 1b. The Xbee node used as wireless switch box with switches (router-mobile switch box)

The status of the input to the pins are sent through 19th and 20th byte of the samples sent by the three nodes.

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
7E	0	18	146	0	19	162	0	64	158	87	183	0	0	1	1	28	255	0	16	251	164

start frame | LENGTH | FRAME TYPE | 64 BIT SOURCE ADDRESS | 16 BIT NW ADDRESS | RECV OPTN | NO. OF SAMPLE | DIGITAL MASK | CHANL MASK | ANLG CHNL MASK | DIGITAL SAMPLES

Fig 1c. The Xbee API data sample format

The Xbee node configured for this paper as digital switch box by making the input pins of the xbee nodes in digital input mode. The digital samples received by the Arduino in byte 19 and 20 are stored in array in Arduino and pin status are used for controlling

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I

II. XBEE CONFIGURATION AND ARDUINO ETHERNET

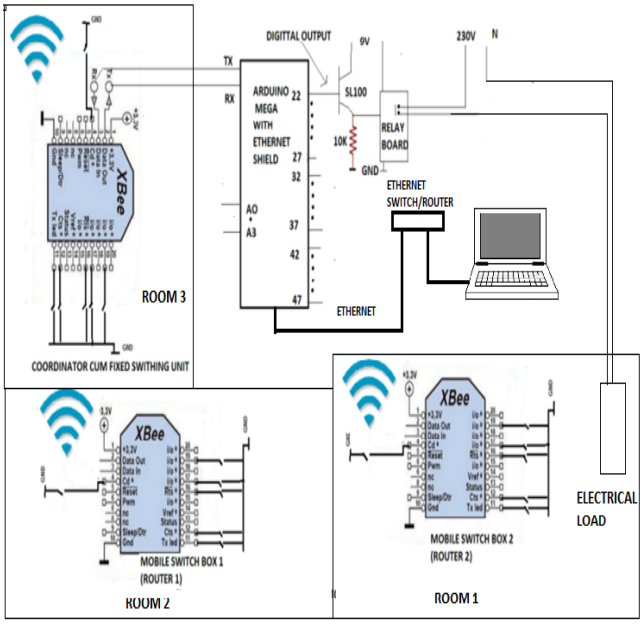

Fig 2 System configuration

The Fig 2 shows the system configuration. The Arduino mega used as controller cum server and the coordinator router nodes. The coordinator communicates to Arduino Mega in Serial1 port of Arduino Mega. All the nodes configured using X-CTU. The coordinator is configured in API mode PANID is set for the entire node as 1234. For coordinator the DH&DL is set to zero. Table I shows the various parameter set for three nodes

TABLE 1: PARAMETER CONFIGURATION FOR XBEE NODES

PARAMETER	COORDINATOR (API)	ROUTER 1 (AT)	ROUTER2 (AT)
PANID	1234	1234	1234
JV	-	1	1
DH	0	0	0
DL	0	0	0
BD [9600]	3	3	3
NB (Parity bit)	0	0	0
SB (stop bit)	0	0	0
D12 [Digital Input)	3	3	3
D7 (Digital input)	3	3	3
D5 (Digital input)	3	3	3
D4 [Digital input)	3	3	3
D3 [Digital input)	3	3	3
D1 [Digital input)	3	3	3
Sampling rate [ms]	1000	1000	1000
Pull-up resistors (PR)	1FFF	1FFF	1FFF

The following Fig 3, 4, 5 shows the configuration mode of the coordinator, router1, router2 respectively

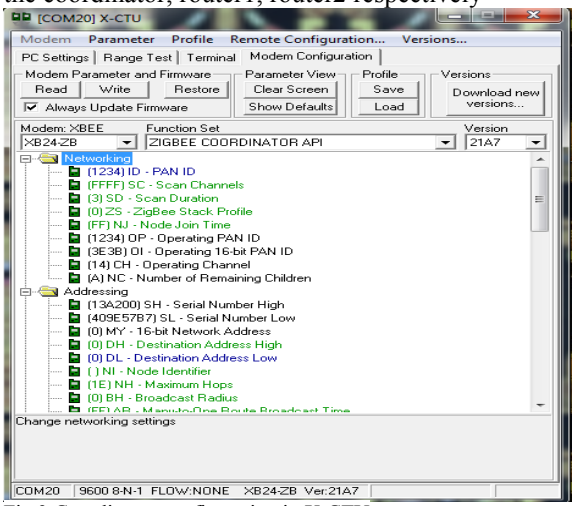

Fig 3 Coordinator configuration in X-CTU

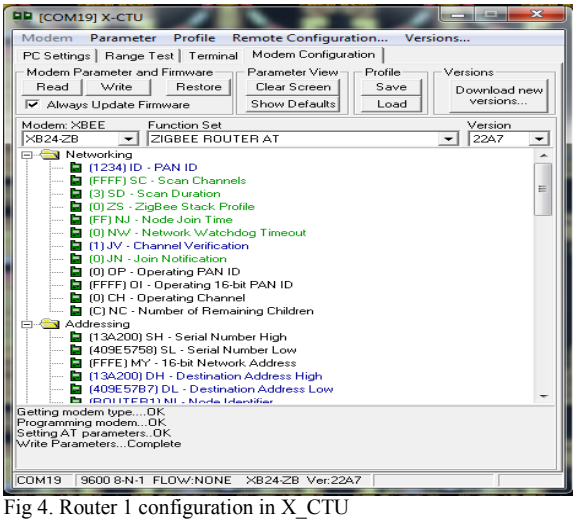

Fig 4. Router 1 configuration in X_CTU

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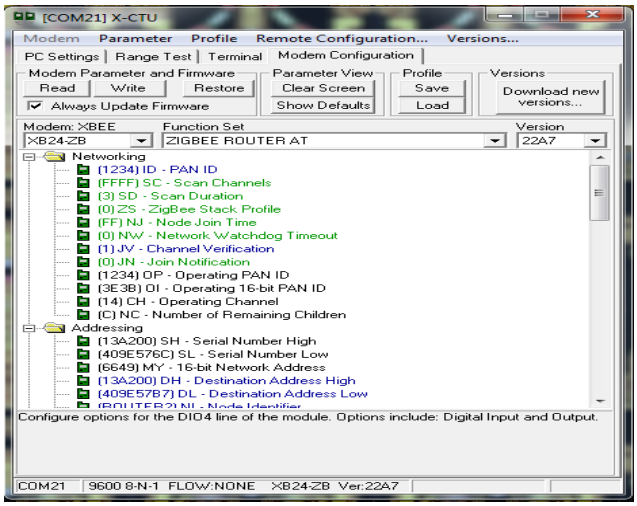

Fig 5. Router 2 configuration in X-CTU

As mentioned in the table the Xbee routers were configured uniformly. We used Arduino mega for running the web buttons and controlling the load. These digital / web button input corresponding control output are shown in table 2.

TABLE2 DIGITAL INPUT ARDUINO OUTPUT CONFIGURATION

XBEE SWITCH	**WEB BUTTON**	**ARDUINO DIGITAL OUTPUT PIN**
Occupancy sensor (INPUT at A0 of arduino) based control		22
DC[12]	Freedom/polymorphing mode	
DC[1]	WD[23]	23
DC[3]	WD[24]	24
DC[4]	WD[25]	25
DC[5]	WD[26]	26
DC[7]	WD[27]	27
Occupancy sensor (INPUT at A1 of arduino) based control		32
DR1[12]	Freedom/polymorphing mode	
DR1[1]	WD[33]	33
DR1[3]	WD[34]	34
DR1[4]	WD[35]	35
DR1[5]	WD[36]	36
DR1[7]	WD[37]	37
Occupancy sensor (INPUT at A2 of arduino) based control		42
DR2[12]	Freedom/polymorphing mode	
DR2[1]	WD[43]	43
DR2[3]	WD[44]	44
DR2[4]	WD[45]	45
DR2[5]	WD[46]	46
DR2[7]	WD[47]	47

III.A.. XBEE ON/OFF SWITCH

The individual pins of Xbee nodes used for digital inputs are connected to on/of tiny switches the other end of the switch connected to ground .If the switch is kept open, then the particular digital input is treated as ON (HIGH) and if the same is closed (earthed) then it is treated as OFF (LOW). The status of the switches are sent to Arduino and stored in arrays in the Arduino (DC-coordinator group (Fixed), DR1-router 1 group, DR2-router 2 group)

III.B.WEB BUTTONS

The Arduino mega acting as web server cum controller. The web page is designed with web buttons. The web page is sent to the client by the Arduino server. On clicking the buttons from the client the client send the button status to the Arduino along with the button id. The status of the button are stored in the array of the Arduino.

III.C COMMUNICATION PROTOCOL

TABLE3 DIGITAL INPUT ARDUINO OUTPUT CONFIGURATION

SRNO	COMMUNICATION PROTOCOL	BETWEEN
1	ZIGBEE	ROUTER TO COORDINATOR
2	SERIAL	COORDINATOR TO ARDUINO
3	IP-ETHERNET	CLIENT AND ARDUINO

The table 3 shows the various communication protocols adapted in this work.

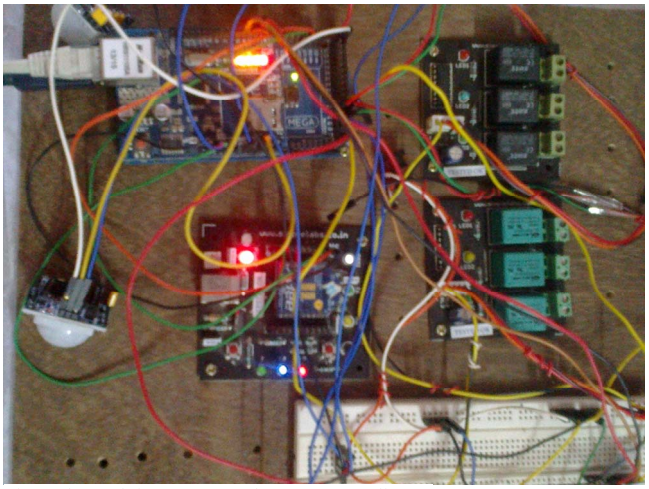
Fig 6 The Arduino Mega +Ethernet & coordinator

Fig 6 shows the coordinator connected to Serial 1 port of Arduino mega and acting as data collector cum local fixed switch box.

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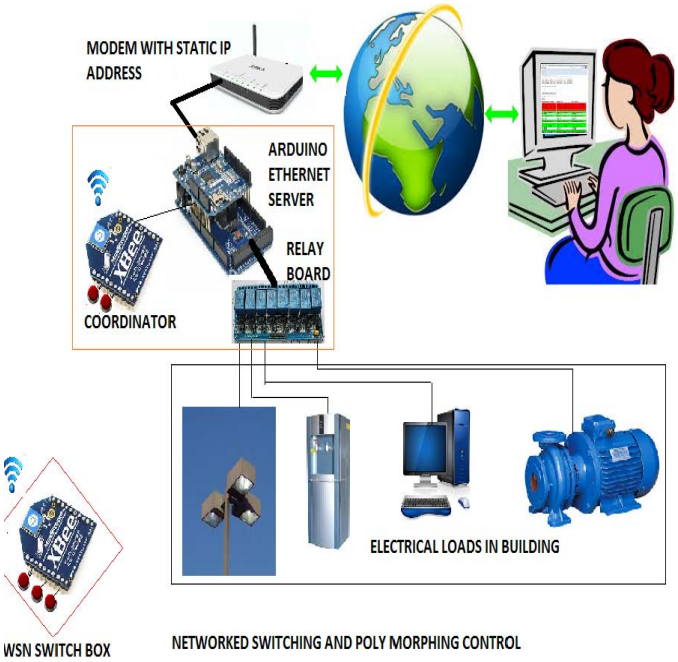

Fig 7. The User Scenario

IV.SAMPLING AND CONTROL ALGORITHM

1. Start
2. Check Serial1 available byte greater than 21
3. To check starting byte check for "7E"
4. Read the byte and store in a array
5. Read the byte b [10], b [11] the last two bytes of address of the xbee node for node identification.
6. Read byte 19 and 20 convert in to binary store in an array
7. Read web buttons store in array.

And operation of web buttons and the xbee node switches for a given load to switch on by Arduino mega.
The fig 8 shows the flow chart for the data sampling and controlling

The coding is made using Arduino 1.0.5, which includes the Ethernet library and text finder library. The web page and the buttons etc. are created using html. The program will check the sample byte greater than 21 bytes in serial 1 port at Arduino .The sample starting byte should be 7E otherwise till finding of the byte 7E the remaining byte will be skipped. After satisfying the above condition the samples were stored in array. The identity for coordinator, router 1 data and router 2 data are checked using last two byte of source address i.e. byte [10], byte [11].

The digital values of the pins are obtaining by converting the sample byte [19], byte [20] values in to binary. After converting them in to binary these bits were stored in separate array. These are the switch status. These switch and the web buttons were made in AND logic in order to give out the digital output from the Arduino. Normally these web buttons must be made high, and then only on local based on the WSN switches. The load will be controlled and also the controlling can be done from web by pressing off buttons. The Arduino must be given power from UPS, so that the buffered data should not be lost.

By using the two routers and one coordinator [gate way node which is acting as one of the switch box and also acting as gate way node for the other node/switch box] we can control maximum 15 loads. There are three occupancy sensor directly connected to Arduino can control three load as indicated in table 2.

V.MATHEMATICAL MODEL

The conventional switching and the operation of the load can be equated in the following equation.

A .Conventional Switch
Operation of load Y=S {S=1, 0}

Y (load on/off)	S(Switch on/off)
1	1
0	0

B.Occupancy Sensor Based Control
Operation of load Y= OC {OC =1, 0}

Y(load on/off)	OC(occupancy detected /not detected
1	1
0	0

In this way "AND" operation or any Boolean operation of web button and wsn switches can be incorporated in the code to meet the various applications.

C. (a)Wsn And Web Switch Based Control
Y=WDD ∧ WSN ∧ M
Where WDD is web button
WSN is WSN node button
M is the mode switch of the respective WSN node {switch box}
IF M=0
WDD=1
Then Y=WSN { control only based on wsn switch}
(b) Y=WDD ∧ WSN ∧ M
IF M=0
WSN=1
Y=WDD {control only based on web button}

D.Poly Morphing Control

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Y=OC ∧ WDD ∧ WSN ∧ M
Y=OC ∧ WSN ∧ M {; WDD=1}

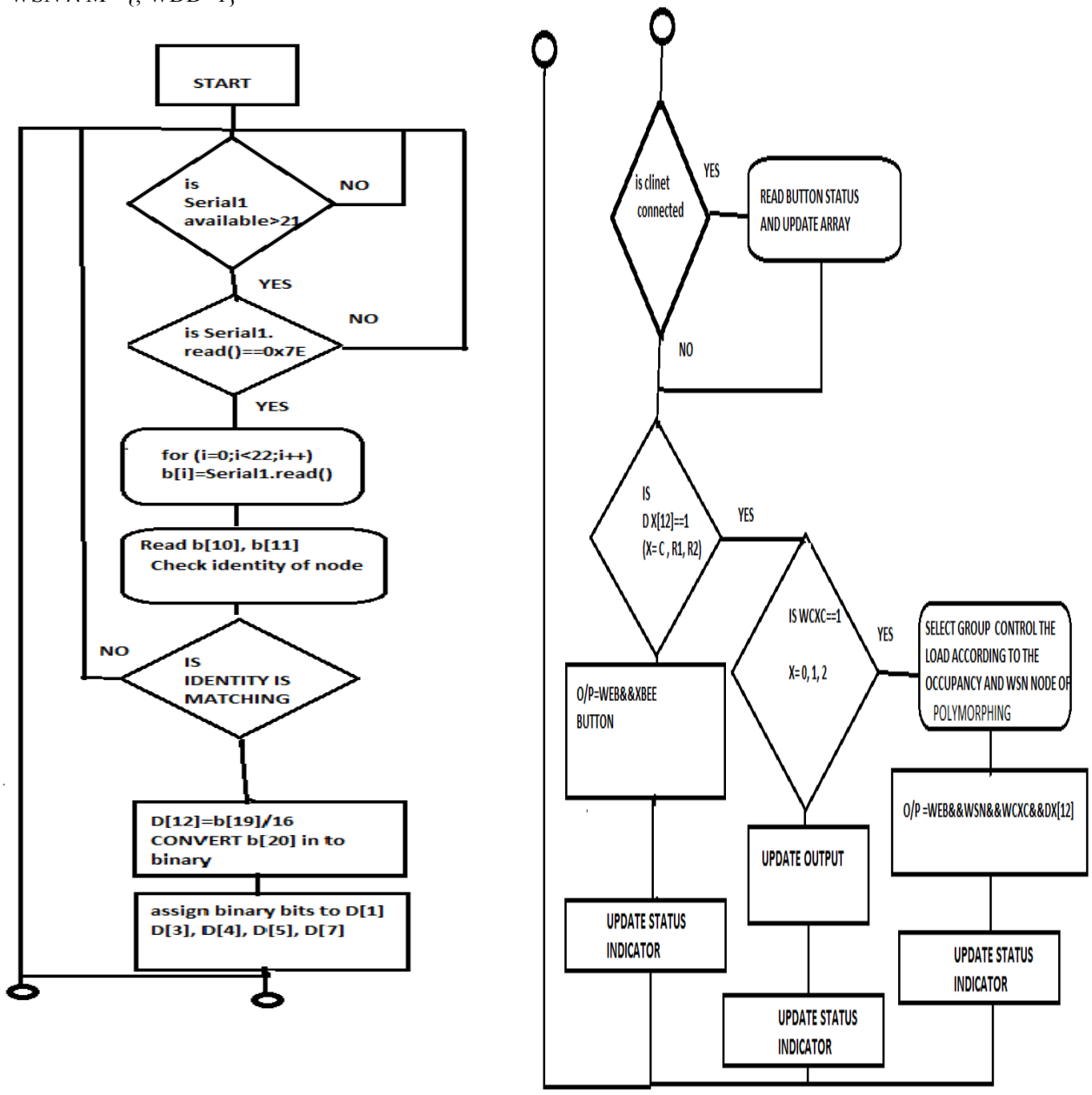

Fig 8 Sampling and control flow chart

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Y -Digital output of Arduino pin	OC	WSN	M	OPERATION
23 TO 27 OUTPUT CONTROL LED	OCCUPANCY SENSOR OF COORDINATOR ROOM WC0C=1	WSN BUTTONS OF ROUTER1	ROUTER 1 MODE 1	COORDINATOR ROOM LOADS CONTROLLED USING ROUTER 1
33 TO 37 OUTPUT CONTROL LED	OCCUPANCY SENSOR OF ROUTER 1 ROOM WC1C=1	WSN BUTTONS OF ROUTER2	ROUTER 2 MODE 1	ROUTER-1 ROOM LOADS CONTROLLED USING ROUTER 2
43 TO 47 OUTPUT CONTROL LED	OCCUPANCY SENSOR OF ROUTER 2 ROOM WC2C=1	WSN BUTTONS OF ROUTER1	ROUTER 1 MODE 1	ROUTER-2 ROOM LOADS CONTROLLED USING ROUTER 1

VI.TEST RESULTS

The web page shows web server buttons to control from the web and the bottom of the web shows the status indicators of the load whether it is on or off in order to monitor from the web. The testing is done by pressing the on buttons for all the loads from web and if the pins of Xbee is open then they shows the high conditions and the digital output connected through relay board is controlled. The fig 9 shows the off condition monitored from the web page served by the arduino mega as server. The fig 10 shows the wsn based node controlled loads keeping web button as 1. Also fig 11 shows the occupancy based control of Router 1, rouiter2 room load status. We have sent the selective signal to another Arduino only for plotting purpose with the SIMPLOT software which is free opensoftware.

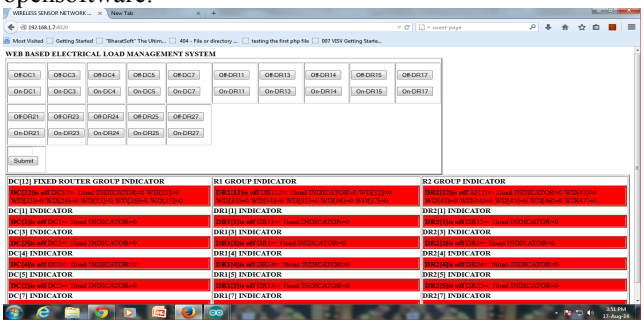

Fig 9 shows the off condition

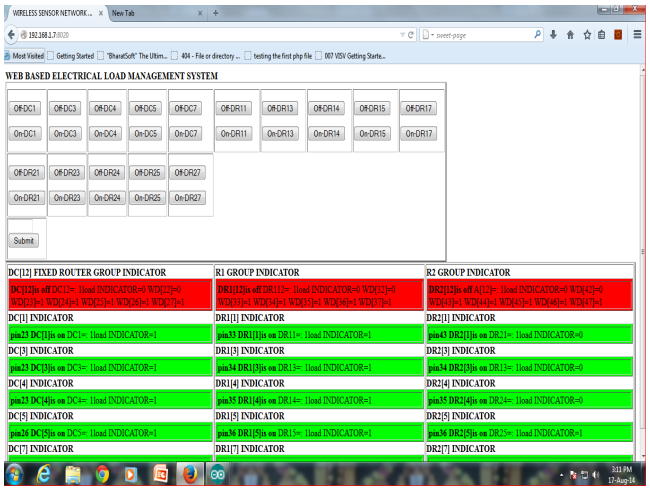

Fig.10 shows the on condition of coordinator SWITCHES , R1, R2

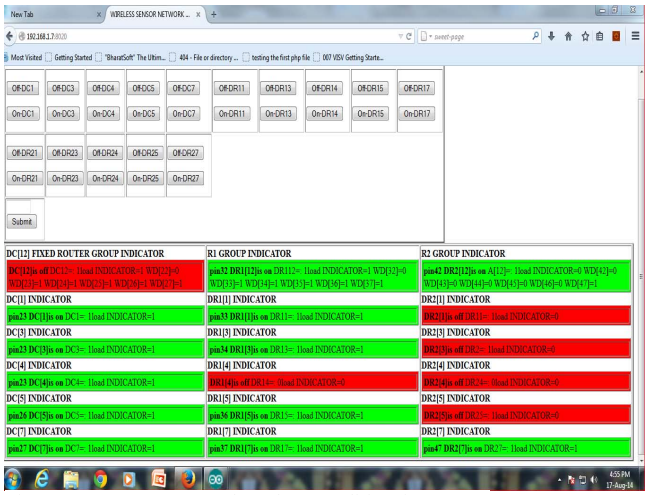

Fig. 11 Occupancy sensor based on condition for R1, R2

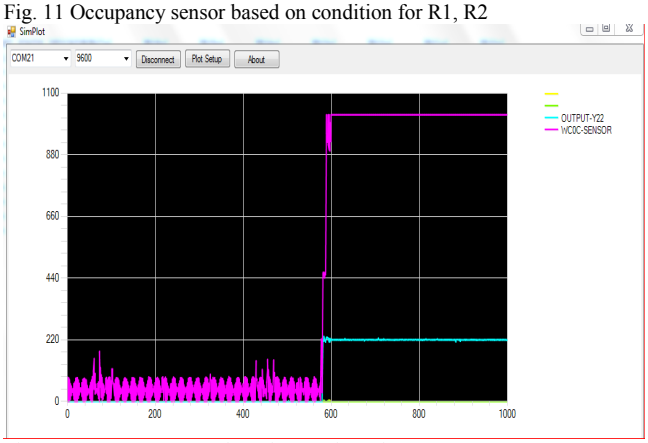

Fig 12 Occupancy sensor based control Mode

Fig 13, 14, 15 shown the results obtaining in various modes by plotting the output in simplot software

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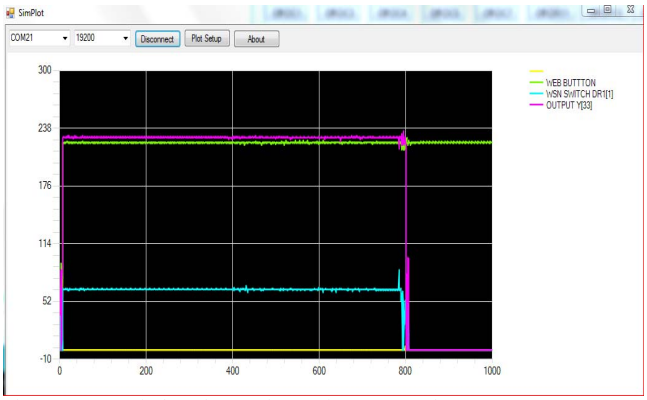

Fig 13 WSN switch and WEB button in AND mode

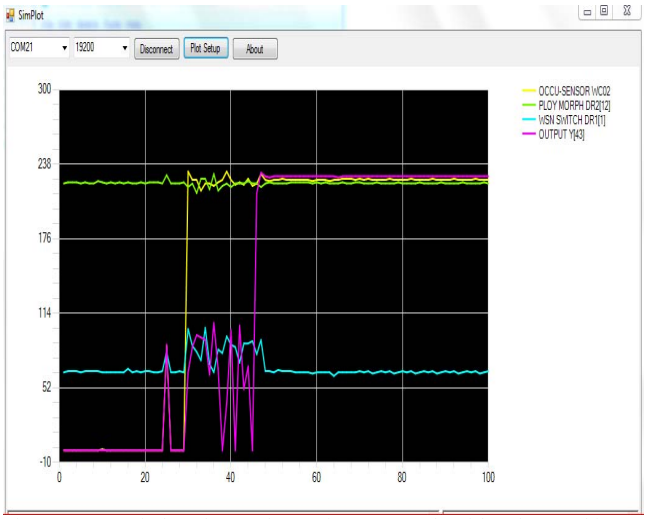

Fig 14 WSN switch and WEB button in AND mode with poly morphing

VII.INCREASED SOPHISTICATION

The Wireless sensor based switching brings flexibility and sophisticated way of controlling the electrical load. The web page buttons and the xbee nodes digital inputs are combined to control electrical load in combination. The web ON/OFF control facilitates, management of load from computer anywhere and also we can create ON/OFF time to automatically switch off the loads, which brings energy efficiency. The occupancy sensor based control brings the energy conservation. Consider a computer lab where large number of computer power to be switched off one by one .This polymorphing control will help the lab attendant to switch off the computers power using single wsn switch box and if he visits another room he can use the same switch box to switch off the light and fans .The location where he moves is detected by the occupancy sensor. The polymorphing switching can be used in homes by visiting the rooms the loads can be switched on as long as occupancy is there the loads continue to work.

VIII EXPECTED APPLICATIONS

1. Large public buildings /campus
2. Large halls/rooms
3. Computer labs
4. Security assistance
5. Customer service centre etc
6. Hospitals
7. Large Auditorium/Stadium

IX SCALABLITY

This work done for total to control 18 nos of load out of which three are occupancy sensor based remaining 15 are web/wsn/polymorphing based control The coordinator , router1 , router2 are independently handling three room load each (5+1) . For increasing scalablity the same set up another three group of rooms to be installed. The web server Arduino can be accessed by respective address. For poly morphing control the wsn nodes must be included with their identity its buttons and its mode in the algorithm.

X FIRE SAFETY & ELECTRICAL SAFETY

The wsn node switches works on 3.3V which is safer than conventional 240V switches. The controller can be kept outside the room. During off condition power is not in the room. The power is fed to the load through relay only when the load is switched on from web or wsn buttons .Hence there is enhanced fire safety.

XI USER SATISFACTION AND ENERGY EFFICIENCY

The user need not to travel to the fixed switch box hence he conveniently operate the load locally or anywhere using web. This bring earlier switch off of the load when not required and thus bring energy efficiency.

XII LIMITATIONS OF POLY MORPHING MODE

Normally the occupancy sensor having in delay setting .If the person is not in occupancy sensor range then the load automatically put off. Hence we have to switch of the loads and leave to other room .This may advantageous in some application and disadvantageous in some applications.

XIII.CONCLUSION

The wireless sensor network Xbee node based switch boxes were developed and tested for controlling the electrical loads in combinations with the Web based buttons developed for this purpose which is driven by the embedded controller. The web page back ground colour for each button in the indicating area GREEN indicates the on

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condition and the RED indicates the OFF condition. The results of web pages are captured and indicated fig 9, 10, 11. The result graph plotted using simplot is indicated in the fig 12, 13,14 There is no need for wiring for the switches, but wiring for the load only is sufficient. This will save the wiring cost. Since there is no wiring for the switches, this eliminates power inside the building when the loads were off conditions. . By making use of occupancy sensor or digital inputs to Arduino, we can bypass the WSN switch boxes to operate only from web or we can bypass web buttons to operate only from the WSN nodes.

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