Design of a Wireless Sensor Network-Based Home Automation System to Reduce Electricity Consumption

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Abstract

Among the many uses made possible by Wireless Sensor Networks (WSN) technology are those for monitoring human and structural health. The revolutionary development that connected WSNs to the internet to become a part of the Internet of the Things (IoT) increased the benefit of WSANs by making applications like home automation a reality. As control capability was added to the nodes, these networks became more useful and enabled the development of more critical applications. This study presents a WSN-powered small-scale home automation system. From a local PC, the system could be used to operate the house.

Keywords: *Home Automation, Appliances, Zigbee, Internet of things.*

1. Introduction

Wireless home automation networks (WHANs) empower monitoring and control applications for home user luxury and efficient home management. WHANs enable a range of use cases, including lighting control, remote control (like air conditioning, TVs, etc.), smart energy utilization (like window shades), remote care for the old, patients and disabled people using wearable sensors which can assert alarms in case of medical emergency, security and safety (like smoke , glass break and motion sensors) [1].

For instance a water sensor can discover a probable water leak and prevent pricey damage repairs, also home automation systems can allow users to program bathroom heating times. Home automation is not reserved to indoors; it can also be utilized in gardens for a more efficient plant life like scheduled irrigation [2]. The rest of this paper is organized as follows, section 2 provides a review of related works, section 3 explains the design methodology, section 4 shows the results and section 5 concludes the paper.

2. Related Works

Many home appliances monitoring and controlling systems have been proposed, in [2] the author offered a home automation system with speech recognition capabilities, the system consists of a Linux PC and a wireless node attached to it, in addition to a wireless node connected to a lighting control system, and a servo motor.

Some proposed home automation systems target power conservation like [3] which discussed different techniques for remote power sensing and controlling, for this purpose using wired communication systems is harder than wireless counterparts in installation and organization, among the wireless media Zigbee is better than Bluetooth, Wi-Fi and others because it has lower power consumption , large coverage area (up to 200 meters diameter), large number of nodes and data rate from 20kbps to 250kbps.

Each sensor node measures current or voltage and sends information to the node's MCU which in turn sends them to the home server through Zigbee Reduced Function Device (RFD), the appliance is controlled using a relay, if the MCU detects an abnormal current or voltage measurement or receives an order from the user it switches the device off, the user interacts with the system through a GUI which sends the desired commands to the home server through Ethernet [3]. The system presented in [4] uses an embedded.

board with Zigbee module for the home server, this design achieves a 100 times less power consumption, and it also reduces cost and size.

In [5] the authors propose internet as a futuristic solution for home automation, since embedded microcontrollers used in wireless sensor networks can handle RFC- compliant IP stacks even IPv6. Authors of [5] have proven that IPv6 overcomes most existing home automation solutions (like X10, KNX, ZigBee and dS).

To tune IPv6 for wireless sensor /actuator networks an abstraction layer that compresses and segments IPv6 packets to suit small frame sizes and low data rates these networks, for this goal the 6loWPAN (Transmission of IPv6 Packets over IEEE 802.15.4 Networks) was developed, the architecture of IPv6 based home automation system is shown in Figure 1[5].

Also light weight HTTP servers can be hosted on embedded devices, the Constrained Application Protocol (CoAP) is a protocol enhanced for resource limited networks of IoT and M2M applications, CoAP includes a subset of HTTP functionalities which have been reengineered for resource constrained embedded devices, the CoAP protocol is used in two famous wireless sensor network WSN operating Systems Contiki and TinyOS [6].

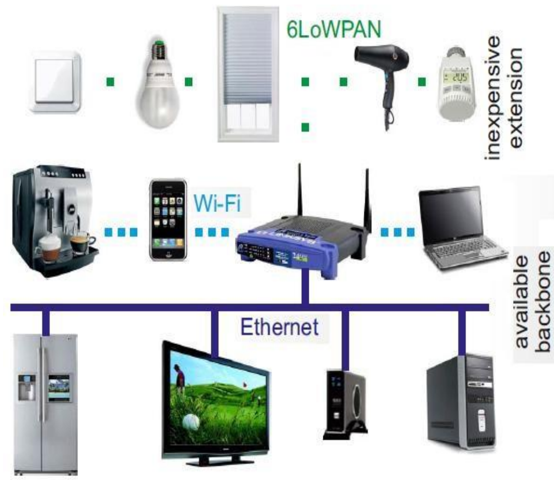

Figure 1: Architecture of IPv6 based Home Automation System

In systems where IP based solutions and legacy technologies coexist a high level middleware can be used to improve flexibility and interoperability, like the Global Sensor Network (GSN) which is based on Java technology, it introduces the concept of virtual sensors [6].

A virtual sensor receives data stream from real sensors or other virtual sensors, a virtual sensor consists of a wrapper class which contains wrapper logic for reading data, processing class (es) which contain the data processing logic and an XML descriptor file for virtual sensor configuration, this XML file contains information about the virtual sensor like geographical location (longitude and latitude) [6]. The Plogg-Blu smart meters provided by Bytesnap ® Company allows users to observe accurately the power intake of their appliances and also makes these appliances remotely controllable [7].

Plogg is built around a specially-designed electrical energy metering microcontroller combined with a wireless unit, The Plogg's unique hardware design allows it to be used adaptably with both the Bluetooth or Zigbee [10], the Plogg-Blu socket powering the device is controlled not the device itself.

Bytesnap® company also developed a computer and mobile application program called Plogg Manager Shown in Figure 2 offers a simple and user-friendly interface for use with either Bluetooth or Zigbee Figure 3 shows Bluetooth enabled devices that can interact with Plogg-Blu socket, Bytesnap also designed a central Plogg Network Controller which allows utility firms to implement a demand response system to avoid large-scale power grid failures and widespread energy blackouts [7], the Plogg-Blu costs around 130$.

Figure 2: Plogg Manager

Figure 3: Bluetooth Enabled Devices that can Interact with Plogg-Blu Socket

3. System Implementation

The home appliances are monitored and controlled using sensor / actuator nodes at 3 points (locations), sensing nodes report devices status to the base node which is connected to the PC, the PC sends the desired settings to the base station which in turn forwards command to the nodes, then the nodes receive the desired settings and execute them. The Nodes use a relay circuit to control the devices operation. A star topology is selected; it is a point-to-point single-hop architecture in which each sensor node connects directly to a base node, as shown in Figure 4.

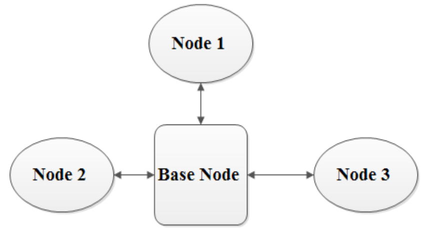

Figure 4: Star Topology

A lot of motes exist in the market, the most renowned ones include the MICAz mote from MEMSIC, MICAz unit price is around 99$, TelosB/Tmote Sky Wireless sensor modules developed from research carried out at UC Berkeley and currently available from both Sentilla® and CrossBow® Technology [8], IRIS which is the latest wireless sensor network module from Crossbow Technologies, Sun SPOT which is a wireless sensor network mote from Sun Microsystems, the cheapest option found was the Texas Instruments EZ430-RF2500T wireless nodes shown in Figure 5 which are programmed using eZ430-RF2500 wireless development tool Figure 6 [9].

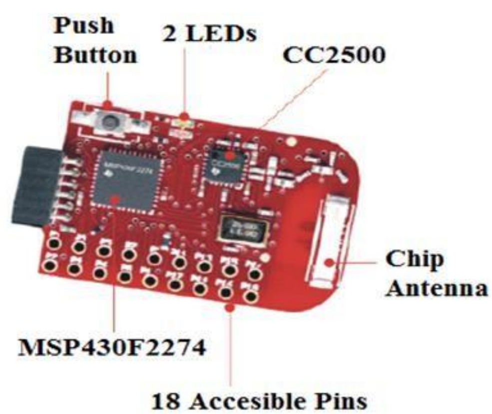

Figure 5: EZ430-RF2500T Wireless Node

Figure 6: eZ430-RF2500 Wireless Development Tool

The tool also acts as a base node and it can be connected to a PC via USB (it is read as a COM port), these motes incorporate the MSP430 microprocessor and CC2480/2500 radio transceiver [9]. Along with the ez430-RF2500 a demo wireless temperature sensor network project is available, the base station consists of the ez430-RF2500 along with one ez430-RF2500T connected to a PC, the PC runs a software that displays temperature data of all nodes joining the network, the nodes are ez430-RF2500T and they send their MSP430 internal temperature sensor data every 1 second to the base station, this project uses SimpliciTI protocol which is provided by TI® for wireless sensor networks [9].

this work was based on the demo project and the nodes and access point firmware we modified, in this system each node controls 3 devices using relays, an air conditioner (AC), a TV, and a Light Bulb, the nodes can be powered using home electrical supply and 3V DC adapters instead of batteries (since the nodes must be always ready to receive status request and settings this seems to be logical, otherwise we will be changing batteries very frequently).

Since the nodes output is a small current logic signal (logic 1 is 3.3V), a relay circuit is needed to interface the node with electrical appliances, the schematic design of this circuit is shown in Figures 7 and 8 respectively, and the PCB Design is shown in Figure(9).

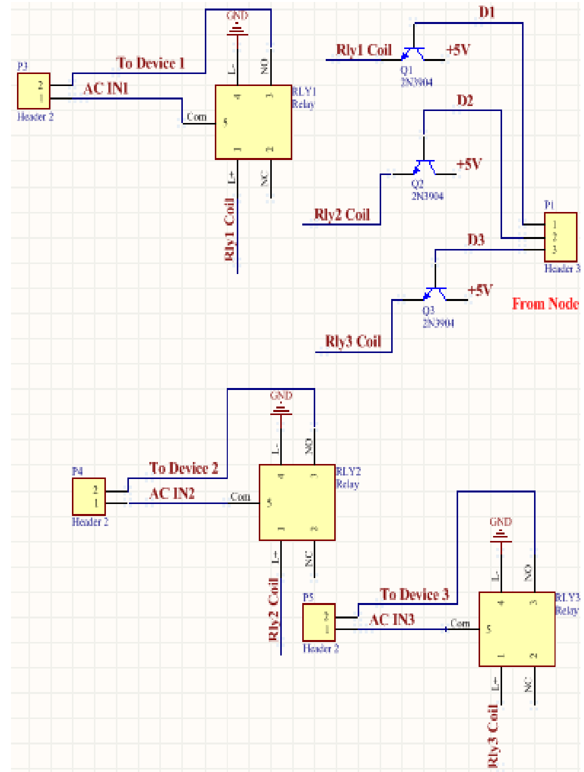

Figure 7: Relay Circuit Schematic Part 1

Since the sensor node is supplied by a range of 1.8 to 3.6V DC then a Zener diode regulator circuit was used to take the 5V from the adapter and provide 3.3V supply to the node.

The Transistors Q1, Q2 and Q3 are used to protect the Sensor node from the Relays coils back E.M.F, LEDs are used to indicate the devices statuses, 3 copies of this PCB need are needed for the 3 nodes, the Relay used is CRD-SS-105D, it's coil runs by 5V DC, maximum AC Switching Voltage is 250V and maximum Switching Current is 7A, this value was chosen according to the estimated air conditioner current rating, TV and lighting use less current).

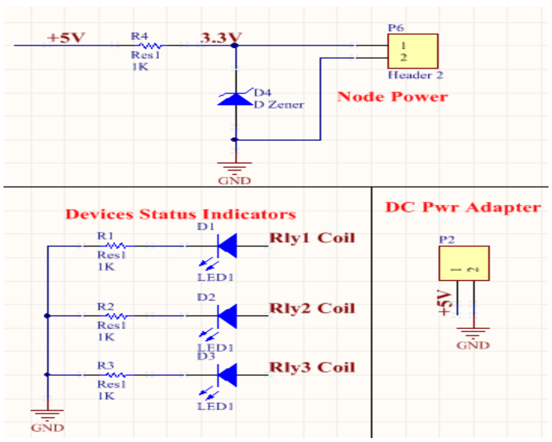

Figure 8: Relay Circuit Schematic Part 2

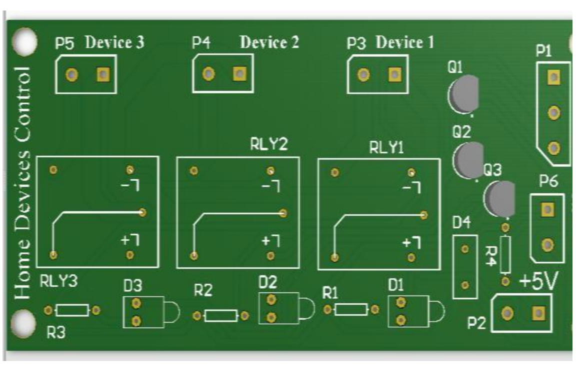

Figure 9: Relay Circuit PCB

The PC software was designed using Visual C#.net, its main form is shown in Figure 10, it also has a login form, after logging in the user connects to the Access Point's COM port by clicking "Connect" button, when the access point is powered it will be waiting for nodes to join the network, after nodes join phase user can request the devices statuses by clicking the "Get" Button of the desired room, user reads device statuses and can set them by clicking on Set devices button of the selected Node/Room.

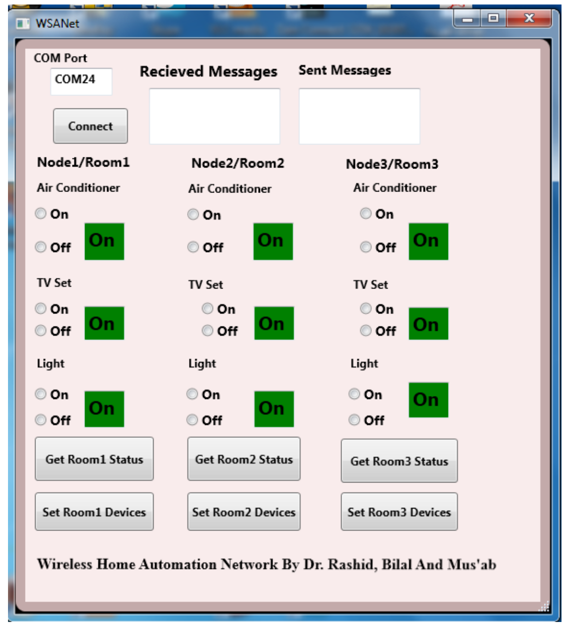

Figure 10: PC Software

Upon user request the access point will request devices statuses from nodes , each node sends the status of its attached devices to the access point, the access point sends the devices statuses to the PC in this frame format "$AXXX#" node address 'A', the nth 'X' device status of device n, the PC replies to the access point by a settings message in the format "$SAXXX#" which includes node address and desired setting, the access point forwards this ,message to all sensor nodes , each node reads the address field of the message , if it is the desired node it performs the required setting , otherwise it discards the message, the sequence diagram of the system is shown in Figure 11.

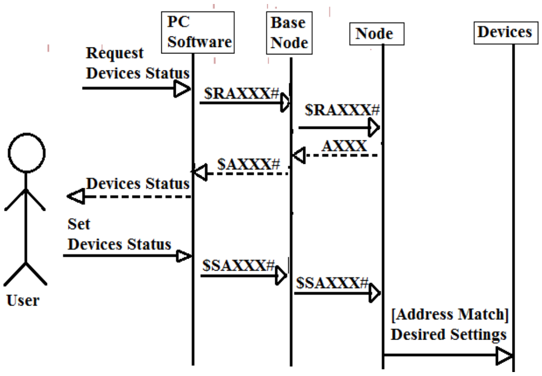

Figure 11: System Sequence Diagram

4. Implementation and Results

In the testing phase the home appliances were represented by LEDs, the nodes are shown in Figure 12.

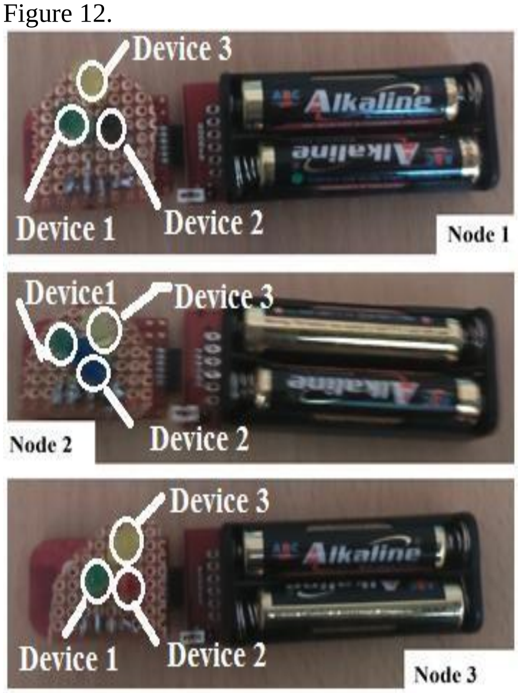

Figure 12: System Nodes

The PC software was used to get and set device status, the devices attached to node 1 were set to (Off/On/On), the devices attached to node 2 were set to (On/Off/On) and the devices attached to node 3 were set to (On/On/Off), nodes status after settings appear in Fig. 13.

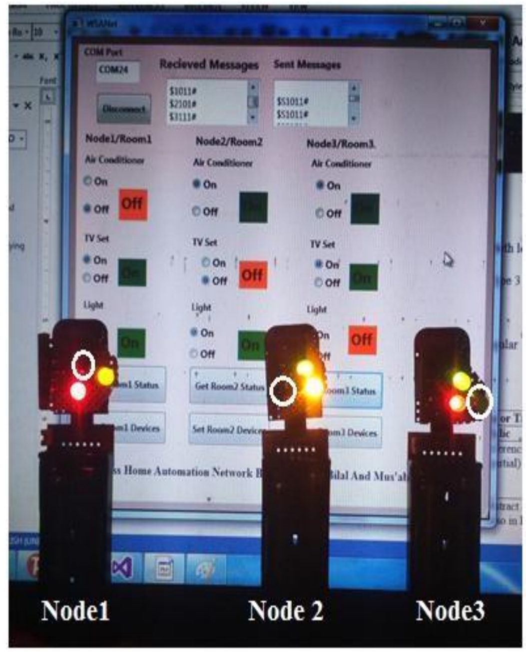

Figure 13: System Nodes after settings And the Software, the white circle highlights the Off LED

5. Conclusion

The relevant literature of home automation have been explored, a system that allows control of home appliances have been proposed and explained.

The proposed system can be enhanced to provide a better home automation experience at a reasonable cost by adding remote access capabilities to it through internet , research in home automation is continuously evolving and future solutions for home automation may be much more advanced and less costly than current solutions.

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