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Multiple Appliances Controlling and Monitoring System based on Wireless Embedded Home Gateway

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ABSTRACT: This paper presents a prototype low cost wireless embedded gateway for remote Home Control and Monitoring system through internet. The gateway in the proposed prototype provides data transfer between the client and the multiple home appliances through internet. The light weight Constrained Application Protocol (CoAP) is used to provide efficient data transfer between the gateway and the Wireless Sensor and Actuator Modules (WSAM). This system uses wireless technology to avoid wired connection between appliances and the gateway. It helps to do complete monitoring and control functionalities of the home environment using wireless sensors and actuators modules than just the switching ON/OFF functionality provided by similar systems. Using the proposed prototype system the existing home appliances can be automated at low cost. This system does not require dedicated expensive components like a server PC as it uses low cost embedded devices.

KEYWORDS: Smart Home, Home Automation, Internet of Things, CoAP, Contiki OS, Arduino

I. INTRODUCTION

Home Automation or Domotics is the automation of household activities for the comfort and security of its residents. Home automation includes centralized control of appliances, lighting, HVAC (Heating, Ventilation, and Air Conditioning), resource management (water and energy) systems and security systems. Home automation may also include additional functions like automatic plant watering and pet feeding and automatic home care for the elderly or disabled people etc. There has been a significant increase in home automation in recent years due to reduced expenditure, higher affordability and advancement in Smart phones and tablets technologies which allows vast connectivity. Emerging concepts like Internet of Things (IoT), Cloud Computing and Big-data are also incorporated with home automation to provide more advanced services and products in the field of Domotics. The overall objective is to provide sophisticated monitoring and control over the day to day household functions to improve convenience, comfort, energy efficiency and security.

In simple sense Home automation means to connect all electrical devices in the home to a central control system that control those devices according to user inputs. The connected electrical devices are intelligent in a sense that a programmable microcontroller with varies sensors and actuator can be attached with them to improve the automatic functioning. The concept of Internet of Things (IoT) can turns the automated home into a smart home. IoT connects everyday objects to the internet, enabling those objects to communicate with each other and complete tasks with the help of sensors and actuator with less user intervention. A smart home can be easily controlled through internet using a Smartphone, Tablet or Computer. The transition of the Internet towards IPv6 with an almost unlimited addressing capacity and emergence of Big-data and Cloud computing capabilities further widens the scope of smart home concepts.

Future homes will be conscious about the day to day functioning like water consumption, energy consumption, and security issues like detecting theft, fire or unauthorized entry. The goal is to improve comfort level while reducing expenditure. The proposed system consists of a prototype model for a low cost wireless embedded gateway. The system can be extended to a fully fledged Smart Home System with two-way communication between Wireless

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Sensors and Actuators Modules (WSAM) attached with home appliances and Client module (Smart phone application) through the internet for remote home automation.

The concept of Smart Home can be viewed as an improvement in the Home automation concept by incorporating the concepts like Internet of Things (IoT), Cloud computing and Big data. The global connectivity of home environment is an important feature of smart home. The proposed system consists of a prototype low cost wireless embedded gateway for remote Home Control and Monitoring system that allows interaction between mobile client and legacy things through internet. In the proposed prototype model, it is focused on the Wireless Embedded Home Gateway which provides internet connectivity to the home automation system. The light weight Constrained Application Protocol (CoAP) is used to provide efficient data transfer between the gateway and the Wireless sensor and actuator modules.

II. LITERATURE SURVEY

Visions of smart homes have caught the attention of researchers for long and considerable effort has been put towards developing technologies for home automation. Smart homes consist of a number of household devices with embedded intelligence that can communicate with each other. Due to the incorporation of the concept of Internet of things to home automation, the potential market of smart home related industry expanded considerably in recent years. There are a number of market-leading companies like Intel, Texas Instruments (TI), IBM and Cisco that are proposing their own smart home architectures for connecting these smart devices. One of the main problems with these architectures is interoperability between devices manufactured by different vendors. In many aspects, these architectures are similar [13].

The Stratecast [13] is one such architecture proposed by IBM which integrates different services in the cloud instead of integrating them at the edge device (like a wireless gateway or router) on the home network. IBM refers this as home in the cloud which utilizes a common service platform to integrate various services accessed by the users. Rather than communicate each other directly, these devices can communicate with a single platform that can take care of the communication between various types of devices and services irrespective of the vendor. Instead connecting all devices directly to the cloud, a better approach is to use a local router or gateway that can act a middleware between the cloud and the end devices. This gateway can be controlled and managed easily and effectively from the cloud.

Some middleware platforms focused on the home environment to transform a residence into a smart home. All most all of them tried to integrate varies technology and services through home networking for automation including sensing of temperature, humidity and illumination, as well as location, mobility tracking and inhabitant behaviour. The Intelligent Home [14] is a simulated intelligent home environment, populated with appliance agents that can interact and coordinate with each other to perform home tasks efficiently by sharing resources. The Aware Home [15] is an example of simulator for ubiquitous computing research which includes human position tracking through ultra-sonic sensors, RF technology and video recognition through floor sensors etc. The Gator Tech smart house [16] employs a service-oriented OSGi framework that facilitates service composition. The RFID tags are attached to electrical devices to detect plugging the devices into power outlets and Smart Floor which functions as a position-only location system.

Various wireless technologies that can support some form of remote data transfer, sensing and control such as Bluetooth, Wi-Fi, RFID, and cellular networks have been utilized to embed various levels of intelligence in the home. In [5,6] researchers have attempted to provide network interoperability and remote access to control devices and appliances at home using a Wi-Fi based home control system using PC based web server which manages the connected home devices. The main disadvantage of these systems is a high end personal computer is required which not only increases the cost of installation but also increases the energy consumption.

A GSM based communication and control for home appliances has also been presented in [7] where different AT commands are sent to the Home Mobile for controlling different appliances. The drawback of this system is that users are not provided with a graphical user interface and users have to remember different AT commands to control the connected devices.

The studies in [8] have presented Bluetooth based home automation systems using Android Smart phones without the Internet controllability. The devices are physically connected to a Bluetooth sub-controller which is then

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accessed and controlled by the Smart phone using built-in Bluetooth connectivity. However, due to limited range of operation (maximum up to 100 m) the system is unable to cope with mobility and can only be controlled within the vicinity.

Researchers have also presented use of Web services, Simple Object Access Protocol (SOAP) and Representational State Transfer (REST) as an interoperable application layer to remotely access home automation systems. Paper [9] introduced a smart home management scheme over the Ethernet network based on XML SOAP standards. The drawback of using SOAP based Web a service is that it is complex and adds overhead to the client and server when parsing the message, resulting in slower operation and higher Bandwidth.

In [10] REST has been presented as a Web-based interaction for controlling household appliances using Web techniques such as HTTP caching and push messaging. Also a Web-based graphical user interface has been developed to manage the home devices. Home automation using Cloud computing has also been proposed [11, 12] where users were able to control various lights and appliances within their home. But it offers more functionality by adding complexity and security risk.

Paper [1] also utilizes HTTP RESTful based Web services as an interoperable application layer for communicating between the remote user and the home devices. But it use heavy weight HTTP instead of much lighter CoAP. The new Constrained Access Protocol (CoAP) is an application layer protocol that is intended for use in resource-constrained internet devices, such as WSN nodes. CoAP is designed to easily translate to HTTP for simplified integration with the web, while also meeting specialized requirements such as multicast support, very low overhead, and simplicity. The Internet Engineering Task Force (IETF) Constrained RESTful environments (CoRE) Working Group has done the major standardization work for this protocol.

III. PROPOSED SYSTEM

The Proposed system consist a prototype low cost wireless embedded gateway for a remote Home Control and Monitoring system through internet. The proposed prototype is focused mainly on low-cost solution for automation of legacy appliances so that to automate the home environment without replacing the existing equipments. The goal is to keep replacement of equipments to minimum and thus to reduce the overall implementation cost, thereby making the reach of the technological advancement to a larger section of the society. Keeping this in mind the approach is to use a gateway that can act as a mediator between the user and the end devices. This paper proposes an embedded gateway which can communicate using wireless radio transceivers with the Wireless Sensors and Actuators Modules (WSAM) attached with the end device and connect them to the internet. Any smart-phone with an internet connection can access the home environment through the gateway.

The gateway in the proposed prototype provides data transfer between the client and the multiple home appliances through internet. The light weight Constrained Application Protocol (CoAP) is used to provide efficient data transfer between the gateway and the Wireless sensor and actuator modules.

The proposed prototype consists of three subsystems: 1. Client module (Smart phone application) 2. Wireless embedded gateway and 3. Wireless Sensors and Actuators Modules (WSAM)

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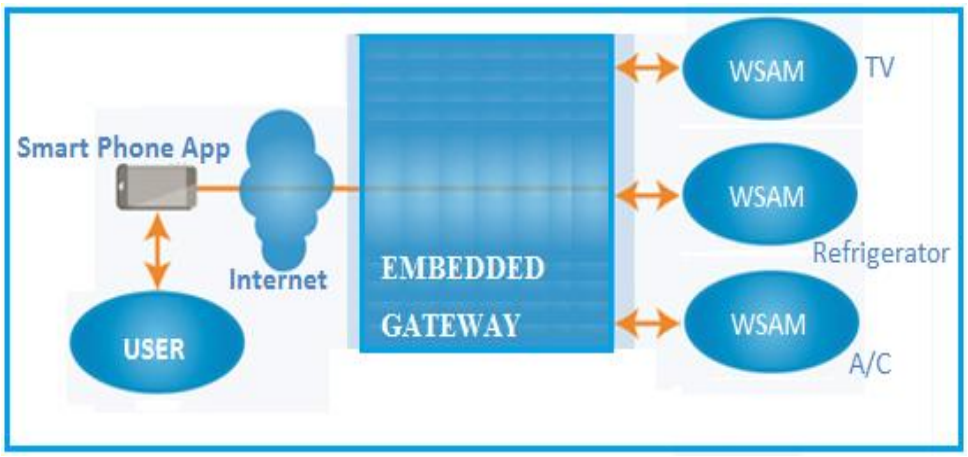

Figure 1: Proposed system architecture

The Wireless embedded gateway is the heart of the System and it feeds the input received from sensors to the User Interface (Smart phone application) through internet and it sends the received commands from the User Interface to the actuators to control the appliances. The Wireless Sensors and Actuators Modules (WSAM) are connected to the appliances to be monitored and controlled. Each WSAM contain a Micro Controller Unit (MCU) which can be programmed according to the requirements of each particular appliance. The Embedded gateway and WSAM communicate using Constrained Application Protocol (CoAP). CoAP is a lightweight protocol that can be used with constrained electronics devices such as a microcontroller. It is a RESTful protocol designed to minimize the complexity of mapping with HTTP for integration with the Web.

The main features of the proposed system are:

- No expensive components like personal computers are required as it is based on embedded gateway
- It is completely based on open source solutions
- Using the proposed prototype system the existing home appliances can be completely automated at low cost.
- The wireless connection between the WSAM and gateway increases the scalability since adding WSAMs to the system not depend on the number of available microcontroller I/O ports.
- Uses light-weight CoAP implementations on Contiki Operating System as application protocol for data transfer between the Wirelesses embedded gateway and WSAM.

IV. IMPLEMENTATION

As mentioned, the "Multiple Appliances Controlling and Monitoring System Based on Wireless Embedded Home Gateway" consists of three modules: Wireless Embedded Gateway, Wireless Sensors and Actuators Modules (WSAM) and Client module (Smart phone application). This section describes the system implementation details.

The hardware parts required for the implementation of Wireless Embedded Gateway are Arduino Mega 2560 Board, Arduino Ethernet Shield and RF transceiver IC (nRF24L01+). The main part is the Mega 2560 Board which contain Atmel AVR 8-bit microcontroller ATmega2560 MCU that can be programmed very easily using an AVR ISP Programmer connected to a Windows or Linux computer. The RF transceiver IC (nRF24L01+) used for giving wireless connectivity is an ultra low power (ULP), highly integrated, low-cost, RF transceiver IC for the 2.4GHz ISM band. The Arduino Ethernet Shield is used to connect an Arduino board to the internet. It uses the Wiznet W5100 Embedded Hardwired TCP/IP Ethernet Controller. The Wiznet W5100 provides a network stack for TCP and UDP.

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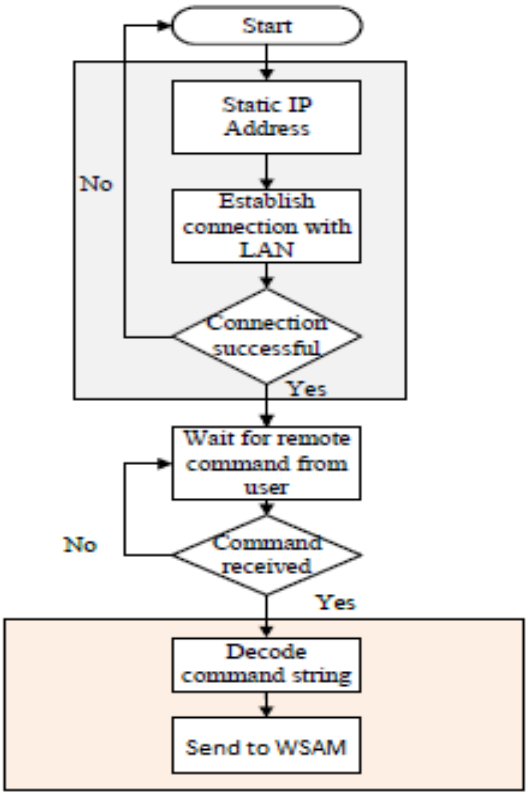

Figure 2: Wireless Embedded Gateway flow chart

The software for Wireless Embedded Gateway is implemented using a Contiki application that runs on any embedded platform which supports Contiki OS. In order to port the Contiki OS to the Arduino Mega 2560 Board, some hardware specific codes need to be added to the Contiki build system. Codes for nRF24L01+ radio driver and Wiznet W5100 driver should be included in Contiki build system. The gateway application is developed using the HTTP server and CoAP client applications which are part of the Contiki core.

Wireless Sensors and Actuators Modules (WSAM) require a microcontroller for controlling the Sensor device and Actuators devices as well as a RF transceiver to provide wireless connectivity. Arduino Mega 2560 Board and RF transceiver IC (nRF24L01+) are used for the hardware implementation of WSAM. The program that runs on WSAM is a Contiki application which is basically a CoAP Server that responds to the requests from the Gateway application running on the Wireless Embedded Gateway. The client request may contain a query for measuring the sensor data or a command to change the actuators for control purpose.

Client module is a smart phone application that interacts with the user and allows the user to access the WSAM for monitoring and controlling it. It is a simple android application developed for the demo purpose of the proposed system which contain user interface for monitoring and controlling home devices.

V. CONCLUSION

In this paper, a prototype low cost home control and monitoring system based on wireless embedded gateway is proposed and implemented. The proposed architecture uses light-weight CoAP implementations on Contiki Operating System as application protocol for data transfer. Any Android based Smart phone can be used to access the home appliances remotely through internet. Using the proposed prototype system the existing home appliances can be completely automated at low cost. Future works can be done on extending this protocol model by including all appliances and services that provide notifications, security, energy-saving, automation, telecommunication, computers

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and entertainment etc and thus make a more intelligent home automation system. Future enhancements should include a sound security mechanism for the system. The incorporation of concepts like Cloud computing and Big data applications may further enhance the intelligent home concepts.

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