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RASPBERRY PI BASED CONTROL AND MONITORING OF SMART GRID UNDER AN EMBEDDED SYSTEM USING WSN AND INTERNET-OF-THINGS

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***Abstract*— The Smart Grid is an evolution of the existing electricity grid. It comprises of a two-way communication where electricity and information are exchanged by the consumer and utility to maximize efficiency. Advancement in technologies has made homes more convenient, efficient and even more secure. Introducing the Raspberry Pi to the world of home automation provides numerous customizations to turn a regular home into a smart home. Raspberry Pi provides a low cost platform for interconnecting electrical/electronic devices and various sensors in a home via the internet network. The main objective of present work is to design a smart grid using various sensors which can be controlled and monitored by the Raspberry Pi via the Internet of Things (IoT). This will help the home owners to provide a simple, fast and reliable way to automate their environment. This paper proposes Smart grid systems consist of digitally based sensing, communications, and control technologies and field devices that function to coordinate multiple electric grid processes. A more intelligent grid includes the application of information technology systems to handle new data and permits utilities to more effectively and dynamically manage grid operations. The information provided by smart grid systems also enables customers to make informed choices about the way they manage energy use.**

***Index terms*— Arduino-UNO, Internet-of-Things, Raspberry Pi, Wireless Sensor Network(WSN), Zigbee.**

I INTRODUCTION

The smart grid is an advanced platform to the way we receive electricity today. In earlier times the demand for electricity was substantial compared to that presently. Since the demand for electricity has tremendously increased, a redesign of the current grid system is much needed. With the technology available in these modern times, the smart grid could be designed in such a manner, that it uses digital communications technology to detect and react to local changes in usage. The system will feature a two-way dialog where electricity and information can be exchanged between the consumer and utility. This can increase or decrease the amount of energy a consumer needs by analyzing the feedback of the two-way dialog. In this system a smart energy meter is installed in every consumer unit and a server is maintained at the service provider side. Both the meter side and the server side are equipped with a Zig-bee module which facilitates communication between the two ends. The Arduino gets the units data from the Energy meter and sends the acquired data to the server (Raspberry Pi) via Zig-bee transmission. The server in the transmission system is connected to the cloud, through this we can able to monitor and control the EB lines of every consumer through Internet. This system, also serves to shut off the consumer's particular product which consumes more units. This system also helps the consumers to monitor their daily usage of electricity through the Internet. The transfer of electricity and information between consumer and utility would increase efficiency, reliability and security.

A. Existing system

In the existing energy meter grid technology, the meter reading process is done by the help of manpower. But this method is subjected to several disadvantages like extra expenses for the billing process.

B. Proposed system

The smart grid involves the application of advanced communications and control technologies and practices to improve reliability, efficiency, and security which are key ingredients in the ongoing modernization of the electricity delivery infrastructure

Advanced metering infrastructure (AMI), which comprises smart meters, communication networks, and information management systems, is enhancing the operational efficiency of utilities and providing electricity customers with information to more effectively manage their energy use.

Grid applications enable utilities to automatically locate and isolate faults to reduce outages, dynamically optimize voltage and reactive power levels for more efficient power use, and monitor asset health to guide maintenance.

II BLOCK DIAGRAM

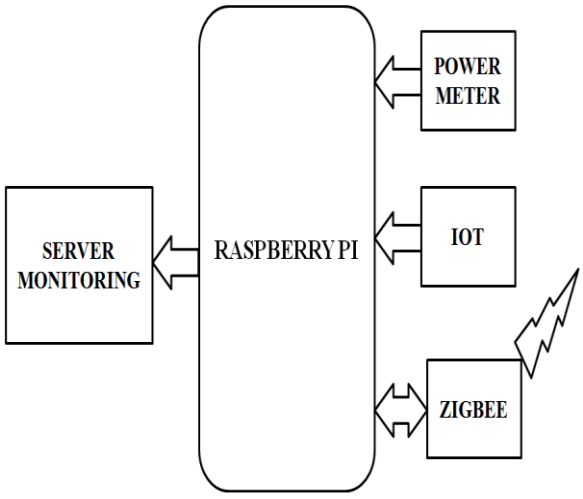

Figure 1: Smart grid EB

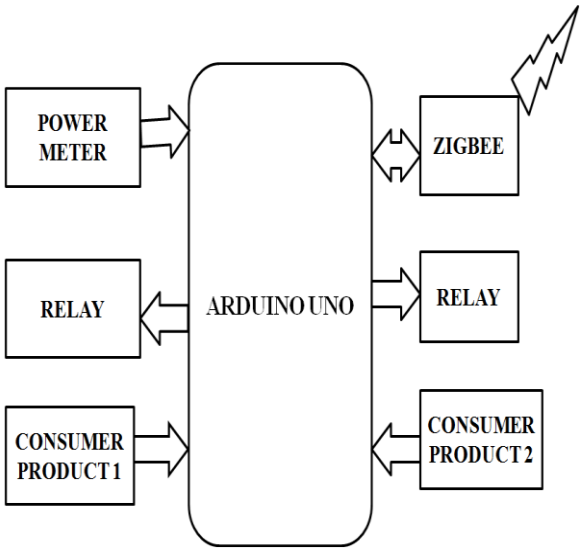

Figure 2: consumer 1

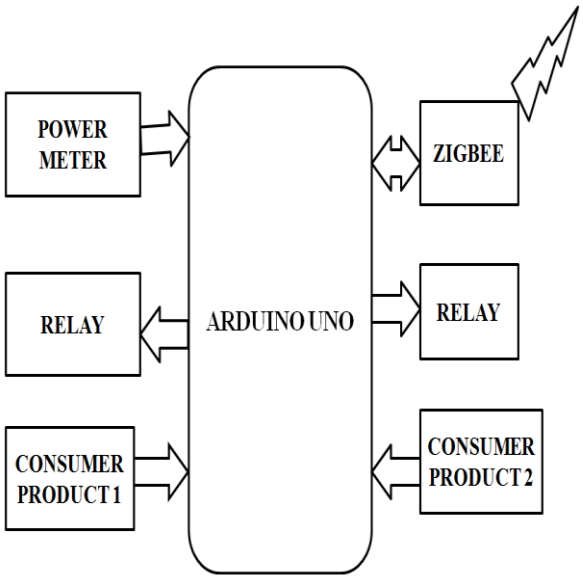

Figure 3: consumer 2

A. DESCRIPTION

Block diagram of an Embedded Systems based Control and Monitoring of Smart Grid using Raspberry Pi shown in Figure 1. Smart grid EB was built around Raspberry Pi and it is attached with Zig-bee receiver. Consumer system is built around Arduino with Zig-bee Transmitter and Relay Circuits. The Raspberry Pi operates on a LINUX based open source operating system called Raspbian OS. This allows more control and flexibility in the software, therefore making it easy to program the Pi. The Raspbian operating system was installed onto Raspberry pi.

a. Consumers section

The unit's data from the energy meter is passed to Arduino, and then Arduino transfers the data to Smart Grid through Zig-bee Transmitter.

b. Smart Grid

The Transmitted data is acquired by Zig-bee Receiver; The Receiver passes the data to the Raspberry Pi and with the help of IOT the Pi

c. Monitoring Section

The EB officials, as well as Consumers can monitor the consumed data through Internet. Additionally Consumers were given an extra feature to shut down their own product. The consumer side is equipped with an energy meter, Zig-bee, relay unit. The Raspberry pi continuously monitors the energy meter reading and calculates the amount till the last usage. These details can be viewed on the monitor and also it will be sent to the EB server through the Zig-bee module. The relay indication unit is provided for the attention of the consumer in case of exceeding normal usage, and control electricity theft in case of any tariff variation by the EB side and also helps the consumers to monitor their daily usage of current through the Internet.

B. SMART GRID EB

Here's the heart of the system, Raspberry pi which receives the Power Consumed Units from the Consumer Side System using one of a WSN component, Say Zig-bee and let the software program receive the values for further calculations like Units Comparison and uploading that Consumer data to Cloud using IoT.

"Raspberry Pi 2" is capable of booting Linux Operating System and thus, it can handle both Cloud & IoT side Python programming.

Rpi handles the WSN component Zig-bee by receiving the Consumer Power Consumption Units using UART protocol and also updates the data into Cloud using the Internet facility provided by Ethernet/Wi-Fi dongle.

C. CONSUMER SYSTEM

This system with Arduino-UNO MCU unit does both internal and external activities regarding communicating with Smart Grid EB and consumer home/industrial automation.

Arduino does transmit the daily usage of Power Units consumed to the Smart Grid EB and also uses it to keep a Log of Power Monitoring system for the individual High Watt Products used inside the home or industry.

Once the Power Unit Crosses the maximum defined level either gives alert to the Consumer or controls the product by switching it OFF depending upon the consumers application side options.

III. INTERNET-OF-THINGS

Whenever an Embedded System plays a role in updating data onto a remote location or device through an Internet IP address using WAN, it's nothing but IoT.

Here in our project, we are uploading and retrieving data from Cloud or any particular Internet IP address using the Internet facility provided default by the hardware in our system (Raspberry Pi 2) at Smart Grid EB Side.

All the data say the Power Unit Monitored at Grid Side, the data received from Consumer Side, Comparison between both Units and Exceeded Units, etc... etc... are possible through this IoT concepts using WAN facility.Updating this kind of Embedded Systems data's are possible in many ways like TCP/IP, UDP/IP, Web-based Apps or Scripts or particular Webpage, etc....etc...

A. DESCRIPTION

The new Pi has a quad-core processor that runs at 900MHz, compared to a single-core CPU that ran at 700MHz in the first generation. It's also an ARMv7 processor rather than an ARMv6 processor, which limited the software available on the original hardware.

Raspbian, a version of Debian compiled for the original Pi's processor, will make another appearance on Raspberry Pi 2, but the ARMv7 processor should also allow volunteers to bring Ubuntu and other OS's to the hardware.

The new Pi will have 1GB of RAM, double the previous version. You'll be able to find links to

distributors selling the new Pi at the Raspberry Pi website.

Raspberry Pi 2 is a "Model B," though there is no Model A yet for the second generation hardware. Model A from the first generation will still be available.

"The current Raspberry Pi Model A+ is $20. We don't know yet when that will be updated. We suspect it will get a RAM upgrade (256->512MB) before a processor upgrade. Keeping the price low is the priority," Raspberry Pi evangelist Matt Richardson told Ars.

Complete Specifications for "Raspberry Pi 2" Model B+

SOC: Broadcom BCM2836(CPU, GPU, DSP, SDRAM)

CPU: 900 MHz quad-core ARM Cortex A7

GPU: Broadcom VideoCore IV @ 250 MHz

More GPU info:

OpenGL ES 2.0 (24 GFLOPS);

1080p30 MPEG-2 and VC-1 decoder (with license);

1080p30 h.264/MPEG-4 AVC

high-profile decoder and encoder

Memory: 1 GB (shared with GPU)

USB ports: 4

Video in: 15-pin MIPI camera interface (CSI) connector

Video out: HDMI, Composite video (PAL & NTSC) via 3.5 mm jack

Audio in: I²S

IV ARCHITECTURE OF RASPBERRY PI 2

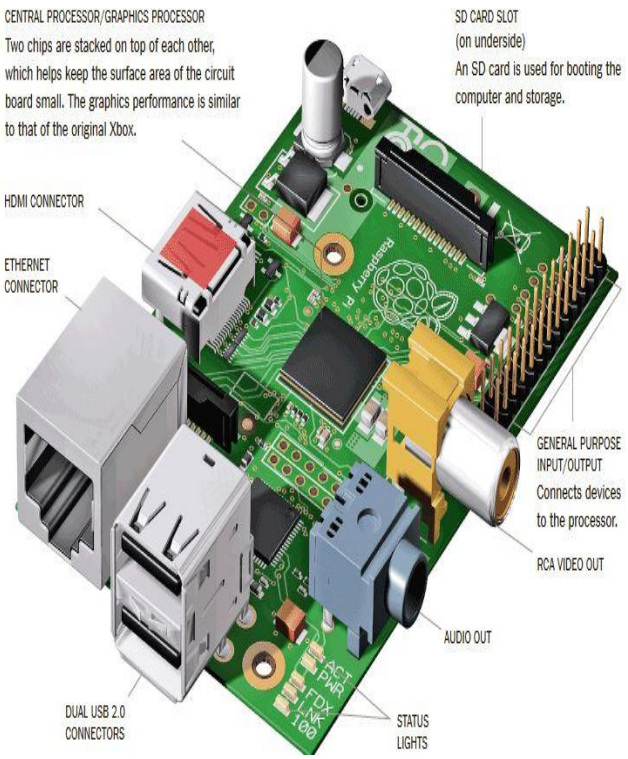

Figure 4: Raspberry Pi

V ARDUINO – UNO

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years, Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

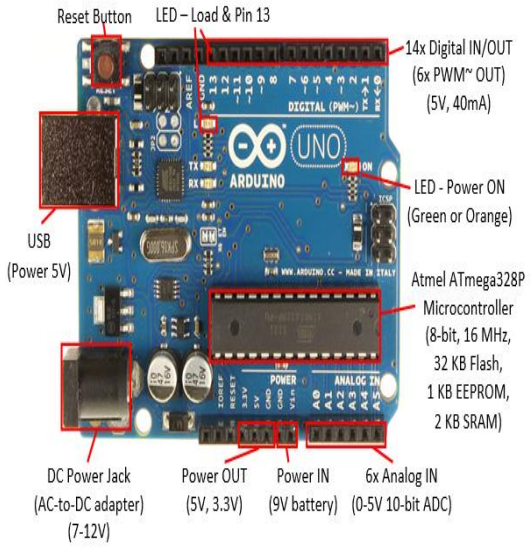

Figure 5: Arduino – UNO

A. Specification of arduino – UNO

Microcontroller	ATmega 328
Operating voltage	5V
Input voltage	7-12V
Input voltage (limits)	6-20V
Digital I/O pins	14(of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V	50 mA
Flash Memory	16 KB (ATmega168) or 32 KB (ATmega328) of which 2 KB used by bootloader
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512 bytes (ATmega168) or 1 KB (ATmega328)
Clock Speed	16 MHz

Table I: SPECIFICATION OF ARDUINO–UNO

B. WHY ARDUINO?

Thanks to its simple and accessible user experience, Arduino has been used in thousands of different projects and applications. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step by step instructions of a kit, or sharing ideas online with other members of the Arduino community. There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Net media's BX-24, Phidgets, MIT's Handy board, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

a. INEXPENSIVE

Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50

b. CROSS-PLATFORM

The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.

The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.

C. OPEN SOURCE AND EXTENSIBLE SOFTWARE

The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the

technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.

D. OPEN SOURCE AND EXTENSIBLE HARDWARE

The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

a. REQUIREMENTS

For successful implementation of Internet of Things (IoT), the prerequisites are

(a) Dynamic resource demand

(b)Real time needs

(c) Exponential growth of demand

(d) Availability of applications

(e) Data protection and user privacy

(f) Efficient power consumptions of applications

(g) Execution of the applications near to end users

(h)Access to an open and inter operable cloud system.

According to another author, there are three components, which required for seamless Internet of Things (IoT) computing

(a) Hardware—composed of sensors, actuators, IP cameras, CCTV and embedded communication hardware

(b) Middleware—on demand storage and computing tools for data analytics with cloud and Big Data Analytics

(c) Presentation—easy to understand visualization and interpretation tools that can be designed for the different applications.

VI. ZIG-BEE COMMUNICATION USING RASPBERRY PI

Zig-bee is a communication device used for the data transfer between the controllers, computers, systems, really anything with a serial port. As it works with low power consumption, the transmission distances are limited to 10–100 meters line-of-sight. Zig-bee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. Zig-bee is typically used in low data rate applications that require long battery life and secure networking. Its main applications are in the field of wireless sensor network based on industries as it requires short-range low-rate wireless data transfer. The technology defined by the Zig-bee specification is intended to be simpler and less expensive than other wireless networks.

Here we make use of an interface of Zig-bee with Raspberry Pi2 for a proper wireless communication. Raspberry Pi2 has got four USB ports, so it is better to use a Zig-bee Dongle for this interface. Now we want to check the communication between the two paired Zig-bee modules.The two Zig-bee must be paired with the same baud rate (for Ex: 9600) with X-CTU Software. Attach the two Zigbee's to the two dongle's and connect one pair on the USB port of the Raspberry Pi2. Connect the other pair to the USB port of a computer or a Laptop. Install the FTDI Driver on the Computer /laptop to provide USB communication.

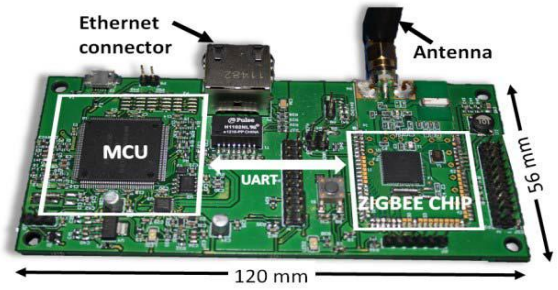

Figure 7: Zig-bee IP gateway prototype.

The response showed inside a red box indicates the presence of an USB device in the module. Write a python script to perform Zig-bee communication which is given.

VIII SOFTWARE USED

The Raspberry Pi can be used to automate a smart grid at a relatively low cost. It operates on the concept as the IoT. There are numerous things that make the Raspberry Pi essential for grid automation but the one that stands out the most has to be the remarkably affordable cost. The vast amount of sensors at extremely low cost makes it's super for smart grid automation. The Raspberry Pi can be programed to be a security system with as many sensors as you desire, for a fraction of the cost.

Raspberry Pi B Model In the present study an IP-based network was established, Python codes were written for the sensors, which were connected to the Pi, a command was then carried out from the network website, which was processed by the Pi and reacted with the connected sensors. The purpose of present study is to build a system of interconnected devices and sensors, which allow the user to control and monitor energy meter via the internet from the Raspberry Pi.

IX Conclusion

Very soon in near future, the traditional grids of today will evolve into a robust, effective, environment-friendly and energy efficient system known as the Smart Grid. It simplifies the work of the electricity board in tripping the supply to a particular customer in case of electricity theft etc. It helps the customer in knowing about the tariff variation. It enables transceiver interfaced with the EB section server as well as in the consumer side. Power consumed by the consumer is monitored by EB through zigbee technology. smart grid technologies are now providing information streams that are beginning to advance utility operations and business processes, while engaging residential, commercial, and industrial consumers in electricity management and even production.

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