Raspberry Pi Based Hazardous Environment Monitoring Using Wireless Communication

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Abstract-This paper presents a hazardous environment monitoring and control for monitoring information concerning safety and security, using wireless sensor network (WSN) with Raspberry Pi technology and the concept of implementation is described in the context of the industrial safety monitoring scenario. The deployed wireless sensor network is used to perform data acquisition with focus on several parameters like current, voltage, temperature, fire, poisonous gas leakage and water level. The advanced system for process management via a credit card sized single board computer called Raspberry Pi based multi parameter monitoring hardware system designed using RS232 and microcontroller that measures and controls various hazardous parameters. The system comprises of a single master and single slave with wireless mode of communication and a Raspberry Pi system that can operate on Linux operating system.

Keywords: Raspberry Pi, Wireless Sensor Network, Industrial.

I. INTRODUCTION

The Proper use of wireless sensor networks (WSNs) can lower the rate of catastrophic failures, and increase the efficiency and productivity of industrial operations. Diversification of remote control mode is the inevitable trend of development of smart appliances. The project proposes a review on remote control system of smart appliances based on ZigBee wireless sensor network. Status of the industrial appliances can be queried and controls through the remote controller. The proposed work presents the design and implementation of a novel wireless sensor network based industry security system with a modular self-reconfigurable remote controller.

The entire system is designed using embedded board with different sensors and a Raspberry Pi that can compile and communicate the data received from the sensors. The Raspberry Pi when operated on the Linux operating system can perform multi-tasking. The design of the embedded board includes the interfacing of different sensors to slave board and connecting the slave to a master board through wireless transmission. The master board uses Raspberry Pi processor and slave board uses ARM7 microcontroller, ZigBee transceiver, GSM, Water level sensor, LM35 sensor, Fire sensor, Gas sensor, Voltage and Current sensors.

The ZigBee transceivers present in slave and master boards uses the process of serial communication and as most of the Computers have more than one serial port there is no need of any special hardware other than a cable. The effective baud rate is the main advantage of using RS232 and also the transmissions is on both directions which mean the inverted logic is also handled with the same. RS232 uses MARK (negative voltage) and SPACE (positive voltage) as two voltage states. So the baud rate is identical to the maximum number of bits transmitted per second including the control bits. The transmission rate of the device is 9600 baud with the duration of start bit and each subsequent bit is about 0.104ms. The complete character frame of 11 bits is transmitted in 1.146ms. MAX 232 IC mounted on the master board converts the 0’s and 1’s to TTL logic.

ZigBee frequency range is 2.4 GHz. These devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. It is typically used in low data rate applications that require long battery life and secure networking. The ZigBee has a defined rate of 250k bits/s, best suited for intermittent data transmissions from a sensor or input device. The Raspberry Pi is a low cost credit card sized Linux computer which has the ability to interact with the outside world and has been used in a wide array of digital maker projects. An open source operating system that uses Linux kernel called Debian 8.3 named Jessie is used on the embedded Raspberry Pi device in an operating system called Raspberry. Linux kernel has been ported to variety of CPUs which are used not only for computers but also for ARC, ARM, AVR32, ETRAX CRIS, FR – V, H8300, IP7000, m68k, PowerpPC, SuperH and Xtensa processors.

In Industrial automation, there are different manufactures producing their own PLCs [3]. The PLCs in an industry is connected with distributed control system (DCS) by protocols such as RS232/485, USB and Ethernet [1] [5]. The DCS has multi-level hierarchical network structure for communication. Due to the hierarchical network structure, the communication becomes complex and high in cost. Complete network from field level to control level is not formed [8]. The java servers used to control the process in a field [5]. Internet of things (IOT) is a fast developing technology that connect all devices with internet [6].
For soft real time systems TCP, UDP and IP protocols are efficient [3]. Embedded web server and Linux based system is cost effective with high performance [3]. The RS232 protocol is sufficient for parameter monitoring and control [2]. The master slave architecture gives good performance in real time control applications [7]. The graphical language is efficient for process monitoring and control [4].

II. SYSTEM DESCRIPTION

The Fig.1 shows the system that is designed with both wireless slave and wireless master where the communication is a half-duplex communication. The master module acts as a bridge device between slave and the Raspberry Pi computer. The master can also communicate with any android devices and compactable with all X86, X64 and ARM architectures that runs any operating system with RS232 functionality. The communication between the master and Raspberry Pi is wireless and Raspberry Pi can be operated through remote computing.

A. Master Module

The Fig.2 shows the components of master module. Data acquired from slave are transmitted to the master which in turn transmitted with the Raspberry Pi via UART serial communication. The master can also communicate with different platforms that execute serial communication.

The entire module functionality is controlled by the microcontroller. One of the major future enhancements of this master module is the in-built USB to UART converter which can directly communicate with the devices that have USB –OTG functionality without using any other driver software and hardware.

The Raspberry Pi processor runs in 3.3V. So the master module has in-built MOSFET based 3.3V to 5V voltage level shifter circuit. No bridging hardware is required as the Raspberry Pi can directly communicate with the master module. A TTL to RS232 level shifter is used to communicate with any other hardware that accepts RS232 protocol.

B. Slave Module

The Fig.3 shows the interfacing of physical parameters like Temperature, Fire, Gas, Voltage and Current. Data acquired from each parameter is collected in slave and sent to Master module through ZigBee transmission. The relay and alarm are also connected to the microcontroller for controlling purpose. The in-built analog to digital (ADC) converter is used to measure the voltage and current. This serial data is transmitted and received over ZigBee wireless modules.

III. SOFTWARE DESCRIPTION

The following software tools are required for designing, compiling and debugging.

A. Keil Software

The Keil development tools are designed for professional software developers, however programmers of all levels can use them to get the most out of the embedded microcontroller architectures that are supported. The Keil development tools offer a completed development environment from ARM, Cortex-R processor-based devices. They are easy to learn and use, yet powerful enough for the most demanding embedded application, feature rich environment optimized for ARM powered devices. Keil also offers an extensive range of evaluation boards and starter kits to quick start your development.

B. Flash Magic

Flash magic can control the entry into ISP mode of some devices by using the COM port handshaking signals to control the device. Typically the handshaking signals are used to control such pins as reset, PSEN and Vcc. The exact pin used depends on the specific device. When this feature is supported, Flash magic will automatically place the device into ISP mode at the beginning of an ISP operation. It will automatically cause the device to execute code at the end of the ISP operation.

C. Raspbian operating system

Raspbian is a free operating system based on debian optimized for the raspberry pi hardware. Raspbian comes with over 35,000 packages and pre-compiled
software bundled in a nice format for easy installation on Raspberry Pi. Raspbian is still under development to improve stability and performance of as many Debian packages as possible.

IV. HARDWARE SPECIFICATION

The following are the hardware requirements for this process monitoring system.

A. Raspberry Pi Model B+

Raspberry pi is based on the Broadcom BCM2835 system on a chip (SoC) that includes an ARM1176JZF-S 700 MHz processor, VideoCore 4 GPU, and was originally designed with 256 megabytes of RAM and later upgraded to 512 MB. The system has either Secure Digital (SD) or MicroSD sockets for boot media and persistent storage. The other features of raspberry pi model B+ are 700 MHz cloak speed, four individual USB host ports, 10/100 Base T Ethernet port and HDMI audio and video output.

B. LPC2148

LPC2148 microcontrollers are based on 32bit ARM7TDMI-S CPU with real time emulation and embedded trace support, that combine the microcontroller with embedded high speed flash memory ranging from 32kb to 512kb. A 128 bit wide memory interface and a unique accelerator architecture enable 32-bit code execution and the maximum clock rate. For critical code size application the alternative 16-bit thumb mode refuses code by more than 30% with minimal performance penalty. Due to the tiny size and low power consumption LPC2148 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-scale.

V. HARDWARE DESCRIPTION

A. Master module

Master module is fully equipped with in built peripherals and there is no need of any bridging devices for communicating with raspberry pi or other platform. Module operates in 5 volt and 500mA of current and also circuit has reverse voltage protection for safe operation. 20 MHz of clock frequency is fed as oscillator input to microcontroller.

a) FT232R is a USB to serial UART interface with optional clock generator which has asynchronous and synchronous parallel bang interface modes.

b) MAX232 level converter is an IC that converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits.

c) 3.3V to 5V voltage level shifter is used to connect with the master with raspberry pi as it can operate with a minimum of 3.3V.

The main functionality of the slave module is as follows.

1) Temperature measurement

The current temperature is converted to an appropriate voltage level using a 3 pin integrated circuit temperature sensor unit (IC LM35DZ). The three pins are ground (GND), voltage source (Vs) and output voltage (V out). Analog to Digital converter (ADC) converts the signal into digital value that is fed as input to the microcontroller. LM35 series is precision integrated circuit temperature sensor whose output voltage can be linearly calibrated in degree Celsius i.e. Linear + 10.0 mV/°C scale factor with 0.5°C accuracy guarantee and rated for full -55°C to +150°C range. It operates in 4 to 30 volts and draws less than 60 μA.

2) Water level sensor

Water level sensor is designed using optocouplers. Opto coupler is a device which transfers the electrical signal between two isolated circuits by using light. It prevents high voltages from affecting the system receiving the signal. It consists of an LED and a Phototransistor in the same opaque package. Whenever the LED is forward biased the light emitted from the LED is transferred to the photo transistor and thus logic high is given to the microcontroller.

3) Voltage measurement

Voltage measures the potential energy of an electric field to cause an electric current in an electrical conductor and most of the measurement devices can measure voltage. The two types of voltage measurements are direct current (DC) and alternating current (AC). The main challenge in measuring the voltage is noise. The potentiometer is used to measure the variable voltage in Slave module.

4) Current measurement

Current sensor is a device that detects the electric current and generates a signal proportional to it. It is used to detect the load current used. The current is measured with ammeter that contains the external resistors that is added to extend the usable range of the movement connected in parallel. The current divider circuits are formed with parallel resistances.

5) Gas sensor

Gas sensor is a device that detects the presence of gases in an area, often as a part of safety system. When the target combustible gas exists the sensors conductivity is higher along with the gas concentration rising.

6) Fire sensor

Fire sensor detects the flame or light source of a wavelength in the range of 760nm-1100nm. It is optical equipment for detection of flame. The change in frequency of the flame is measured by the sensor.

7) ZigBee module

ZigBee modules are advanced RF transceivers operating in license free, 2.4 GHz frequency band. It is a low
power, low cost wireless mesh networking standard. The ZigBee transceivers present in master and slave module uses the process of serial communication. This module can achieve transparent data transmission between many devices, and it can form a MESH network. The target application domain are aimed at industry, home automation, telemetry and remote control.

8) GSM

Global Standards for Mobile communication (GSM) is a set of standards for cellular networks. It is used to send SMS, make and receive calls and do other GSM operations by controlling it through simple AT commands from micro controllers and computers. It comes with standard RS232 interface which can be used to easily interface the modem. It works on frequency 850, 900, 1800 and 1900 MHz frequency.

VI. RESULT

The sensors, GSM and ZigBee transceiver are deployed in the field. The information concerning the industrial environment is send to the Master module which is the raspberry pi by the slave module through ZigBee wireless communication. Whenever the sensors detects the extreme conditions the information is send to the master module and the concerned person can take the necessary actions. Also the message regarding the extreme conditions are send as an SMS to the concerned person.

VII. CONCLUSION

This paper has described the design and implementation of a wireless sensor network in global industrial monitoring using Raspberry Pi. It prevents people from dangerous situations like fire accident, high voltage, high current, etc. From financial standpoint, missing, damaged, or malfunctioning can be reduced and has proven to be a trusted and increasingly applied solution in commercial settings, saving operating expenses and most importantly, human lives.

VIII. FUTURE WORK

The system can be enhanced for wave form representation of data in an excel sheet using raspberry pi. The additional slaves can be added for measures various other parameters. Also controlling action can be set for some predefined cases in the master module which enables the automatic operation at certain cases. A dedicated video processor can be used in raspberry pi to display graphical and three dimensional view of the industry.

REFERENCES


