Integrating GSM and Zigbee Wireless Networks for Smart A2 farming Enterprises in Zimbabwe

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Abstract: ***The paper aims to present a possible solution to farming automation in the Zimbabwean agricultural sector. This is done by presenting a model of a GSM mobile network combined with Zigbee wireless network to come up with a multi monitoring and control system capable of taking care of a large agricultural environment. Human farm workers are able to get data and send control data from anywhere in Zimbabwe by sending and receiving messages over a GSM network to and from a master controller. The master controller communicates with remote/ sensor nodes which are scattered in the different fields over a zigbee network. It is this master controller which sends query commands to sensor nodes to gather sensor data before sending the gathered data to the mobile user. Control commands send by the mobile user also pass through the master node before being channeled to the appropriate sensor node by this master node. The master node will consist the LPC2148 microcontroller while the sensor nodes will comprise the PIC16F877A. Attached to the master node is a real time clock which keeps track of real time which is displayed on LCD. Thus the system can keep track of the maximum and minimum daily temperatures for the day. These values are displayed on LCD and can also be queried by the mobile user at any time.***

Keywords: GSM, Zigbee, Remote monitoring, LPC2148, PIC16F877A, Smart A2 farming, GSM modem, Real Time Clock.

1. Introduction

The design aims to take advantage of the technological advancements in the recent world to come up with a dual wireless communication system to monitor and control the commercial farming area which may comprise a number of sections/fields which are spaced. Each of the fields will contain its sensor and actuator node. These sensor nodes are controlled by the master node via Zigbee network while the master node communicates with the mobile user over GSM network. Therefore except for sensor and actuator connections to the microcontrollers, all the communication has been restricted to wireless and no cables, which are susceptible to mechanical damage, are being used. Zigbee is a wireless communication protocol which falls under the IEE802.15.4 standard. At the IEE802.15.4 level it utilizes the MAC and PHYSICAL layers. GSM is a standard used to describe protocols for 2G cellular networks used by mobile phones. It was developed by the European Telecommunications Standards Institute (ETSI). Thus, these are the two wireless protocols which are being brought together into one system. The master node will consist of the LPC2148 as the controller. Choice of this microcontroller has been due to its speed, presence of inbuilt RTC and presence of two serial ports. One serial port will connect to the GSM modem while the other will connect to the Xbee module responsible for Zigbee communication. The sensor and actuator node has been implemented using the PIC16F877A microcontroller. The implementation of sensor node could have been done using the AT89S52 but the absence of in-built Analogue to Digital converter made the choice for PIC more favorable. Figure 1 shows the hardware setup of the proposed system. It illustrates how the Master node is at the heart of the system coordinating the sensor nodes and the mobile user. All communications have to pass through the Master node and so the Master node should be robust, fast and positioned such that it has adequate supply of power. It will be more ideal to position the master node in a place where it can have AC power and a backup system say from a battery. Also the positioning of the Xbee module aerial should be out of walls to increase the range of transmission of the Xbee modules.

2. Motivation

Zimbabwe is a country whose economy has a high dependency on Agriculture. A2 farming is regarded as a commercial entity which needs high capital investment and high outputs. The farming area can be divided into sections which may be spaced in some way to form farming fields. A way of electronically monitoring and controlling these fields is a huge advantage to the farmers. More so, a centralized way where all the monitoring and control can also be done at the same point is of paramount importance for increased productivity. This has driven this author into coming up with a model to accomplish these tasks. To add to that, it has been discovered that during the hot season (summer) it is vital that plants be irrigated during the night so that more time for water absorption is available. The system again comes to the advantage of the farmer as no one takes the risk of going out at night to switch ON pumps and risking snake bites and other night animals.

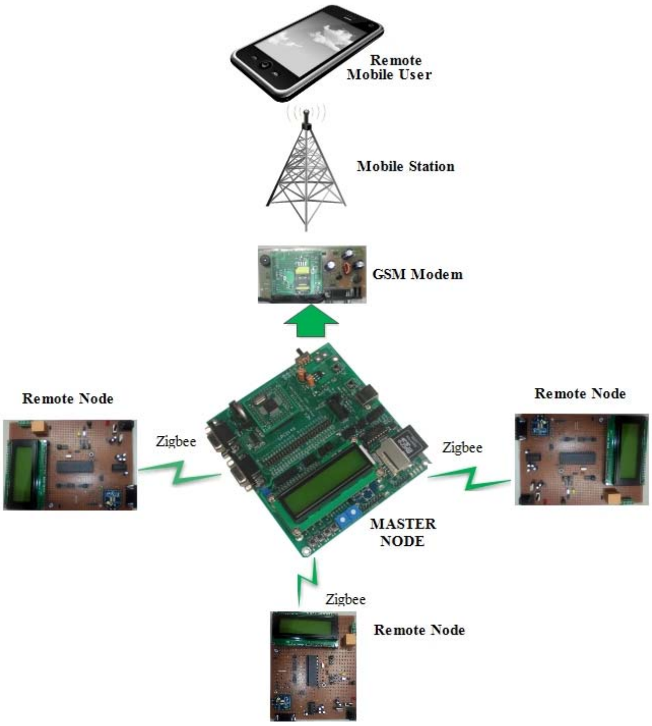

Figure 1: General overview of the system hardware implementation setup.

3. Existing Systems

A large number of systems implementing one of Zigbee or GSM communication are in wide use for a variety of applications. In [1] Two sensor nodes exist where one is dedicated for temperature and humidity measurement and the other is for light and gas sensing. The sensor nodes communicate with a PC server where data is stored using Zigbee. This data can be accessed remotely using an internet facility called drop box. Thus there is processor – to- PC communication and no processor to processor communication and no GSM implementation.

The system in [2] implements a PC as the main control center for visual monitoring and to input control commands. There are several nodes which pass data to a master node so that the master can pass data to Ethernet for online control. It can be seen that all the nodes including master node have implemented the ARM microcontroller (LPC2148). The system also uses Zigbee protocol for inter node communication.

The implementation in [3], although it is not an application specifically designed for an agriculture setting, illustrates the concept of inter-processor communication using Zigbee. The master has the capability of querying the sensor node and getting information required. However, the communication is strictly confined to these two nodes and no other third party is there to request data. The system in [4] again uses a sensor node and central PC server which communicate over a wireless network. PC has the capability to send SMS while in [5] parameters like humidity and temperature are sensed and data can pass through zigbee routers until it reaches an upper server, which is a PC for storage. The temperature and humidity values are continuously transmitted. In [6] environmental conditions of temperature, humidity, pressure and sunlight are captured at the sensor node which uses SiLab C8051F020 as the controller. The values are send over a Zigbee network to a PC central station for storage and display.

4. Proposed System

As stated earlier on, the proposed system comprises an LPC2148 master node and PIC16F877A sensor node. Communication between master node and sensor nodes is accomplished using a Zigbee wireless network whilst communication between master node and mobile user is fulfilled using a GSM mobile wireless network. The parameters being monitored at the sensor nodes are atmospheric temperature, humidity and presence of fire. The sensor nodes can also actuate irrigation pump system (control). The system is supposed to keep track of the current temperature of the day, maximum recorded temperature and minimum recorded temperature for the day. The time at which the max and min temperatures are detected is also logged into the system. This is made possible by incorporating the Real Time Clock at the Master node. Maximum and minimum temperature for two successive days are kept i.e. present day and previous day values. These values are reset at the end of the day i.e. at 00:00:00 Hrs. At 12am the values recorded for that day are moved into previous day storage variables and the current value memory locations are reset such that, the Maximum temperature is reset to 0^oC while the Minimum temperature is reset to 50^oC. This is based on the assumption that atmospheric temperature cannot reach 50^oC. Thus the values for the new day can be captured and stored. Therefore, it can be seen that this system is unique in that it incorporates microcontroller to microcontroller communication over zigbee, Mobile user can request data from sensor node through master node, real time clock for real time data updates and data available on demand except in emergency e.g. fire or when min or max values are detected. For the hardware implementation a single sensor node is going to be implemented due to limited hardware availability. Figure 2 shows the architecture of the Master node which is going to be implemented in hardware and Figure 4 also shows the implemented sensor node.

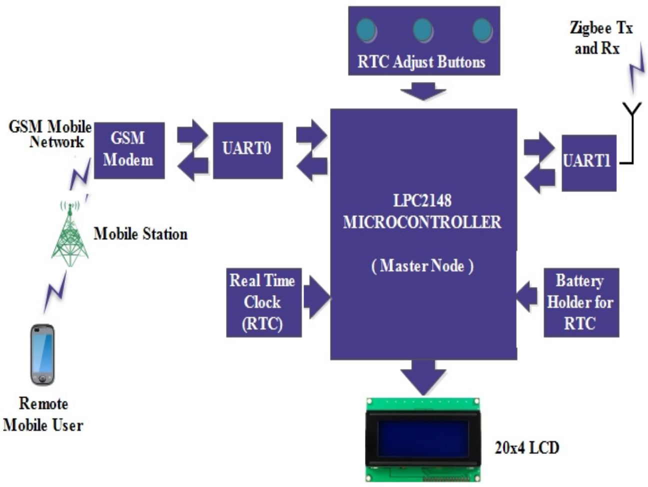

Figure 2: Architecture of the Master Node controller

4.1. Software Descriptions of the Master Node

a) Keil: Keil is a Microcontroller Development Kit from Keil used in the development of applications to run on AEM based microcontrollers. Specifically, ARM MDK is used in the development of this application. Thus in keil we develop embedded C code for the LPC2148 microcontroller, compile it and even debug it if necessary. A hex file is generated which is 'burnt' into the LPC2148 so that the application can run in hardware. Flash Magic tool is used to transfer the hex file into the microcontroller chip.

b) GSM Commands: GSM commands are used in the configuration and control of the GSM modem. A wide variety of such commands exist but only those critical to this application shall be used. Some of the commonly used commands in SMS processing are as follows:

"ATEO": Used to turn OFF the echoing of commands since this can confuse the console
"AT+CMGS=": Send an SMS
"AT+CGMR=": Used to read an SMS. If AT+CGMR=1 then it means read the first message
"AT+CSDH=": Show text mode parameters. If '1' do not text header values and '0' show the values in result codes.
"AT+CMGD=": Is used to delete messages, for example, AT+CMGD=2 means delete the second message

4.2 Hardware Descriptions of the Master Node

The explanation below gives an overview of each of the hardware components used at the Master node. This description will also illustrate how each of these pieces of hardware will contribute to system functionality.

a) LPC2148 Microcontroller: This is an ARM based microcontroller developed by NXP Phillips company. It is a 32 bit microcontroller containing 64 input outputs ports. This microcontroller is used in this implementation as the controller behind all the operations at the Master node.It receives query commands from the mobile user and responds accordingly. It also receives control commands which it uses to actuate the sensor nodes. It also receives sensor data from sensor node and stores these values. If the data received from sensor node requires immediate response, for example in the presence of a fire, the Master node immediately relays that data to the mobile user. The master node also contains a display to show the current and also the maximun and minimum temperatures recorded so far for that day.

b) UARTx: The LPC2148 comprises two serial ports namely, UART0 and UART1. These are full duplex ports consisting of transmit and receive buffer registers. The UARTS are used for connecting the GSM modem and Xbee modules respectively so that data can be transmitted serially to and from the mobile user and sensor node respetively. The transmit and receive buffers are of 8-bit size so can hold data equivalent to a character data type. Flags are used to show the presence of received data and also to show whether all the data in the buffer has been transmitted.

c) 20x4 LCD: This is a character LCD consisting 4 rows which can hold upto 20 characters. The LCD is used to display Real time clock value and also the maximum and minimum temperatures which have been recorded for that day and time at which these values have been recorded. The code snippet below shows a way of configuring the LCD for data reception using 4 data lines instead of the available 8 lines.

```
void init_lcd (void)

{
  cmd_send (0x28);   /* select 2 lines, 4
                        bit mode */
  cmd_send (0x01);   /* clear LCD */
  cmd_send (0x0C);   /* display ON cursor ON */

  cmd_send (0x06);   /* increment cursor */
}
```

d) Real Time Clock: The module provides realtime time update of the current clock time. It is used as the determining module to mark the end of another day and beginning of a new day. It also brings about actual time at which critical events in the system occur. Apart from the system power supply, another separate real time clock backup system is available so that the time settings are not easily corrupted by power cuts. However despite that an interface is provided for adjusting the time. The listing which follows in Figure 3 shows a code snippet for configuring RTC and asociated interrupts.

```
void initialize_rtc (void)

{
/*-------------- VPBDIV setting --------------------------- */
   VPBDIV=0x0;

/* ------------- Initialize Real Time Clock ------------------ */

   CCR=0x02;      /* Reset the clock */
   ILR=0x03;      /* Clear the Interrupt Location Register */
   HOUR=14;       /*Entering the current time */
   SEC=0x0;
   MIN=31;

/* ---------Initialize Vectored Interrupt Controller (VIC) ----- */

   CIIR=0x07;
   VICIntSelect=0x000;
   VICIntEnable =0x2000;
   VICVectCntl0=0x2d;
   VICVectAddr0= (unsigned long) read_rtc;

   /*read_rtc is the Interrupt SR */

}
```

Figure 3: Initialization and configuring interrupts for real time clock

e) GSM Modem: This is a hardware module capable of accomplishing GSM mobile communication. It can be used for both voice and text communication. However for our application it shall be used only for text based communication and it will act as the intermididte hardware between the microcontroller and the GSM network such that communication can be established between the microcontroller and the mobile user. The modem is connected to UART0 of the LPC2148 microcontroller for serial data communication.

f) Xbee Modules: These modues from Digi International are used for transmitting data using the Zigbee protocol. Xbee Ver2 modules are used in the implementation. Configuration of these modules is been done using using X-CTU software utility (Xbee Configuration and Testing Utility). One Xbee lies at The Master node side while the other at the sensor node side and they are connected serially to the microcontrollers.

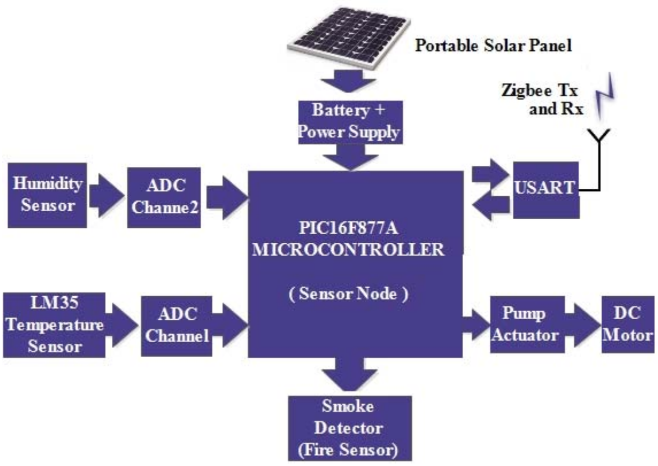

Figure 4: Sensor Node Microcontroller and its associated peripherals

4.3. Software Description of the Sensor Node

a) MPLAB: This is an Integrated Development Environment used to develop code, compile it and debug for the PIC16F877A microcontroller. The code is developed using C language and can also be developed using assembly language but using a different compiler.

b) Hitech C Compiler: If code is to be developed in MPLAB using C language then a C complier has to be installed. The compiler used in this application development is the Hitech C Compiler which will compile and link all the siurce files developed for the application.

4.4 Hardware Description of the Sensor Node

The hardware description of the sensor node modules and how each contributes to system functionality is as follows:

a) PIC16F877A: This microcontroller from Microchip is used in the implementation of the sensor node. It monitors all the sensors attached to it as illustrated in Figure 4 and also actuates the motor which drives the pump. Locally it contains memory variables to log in maximum and minimum temperature and humidity values such that if a new max or min temperature is detected then the new values are send to the master node for storage. The current temperature and humidity values are only supplied to the master node on demand.

b) USART: This is a Universal Synchronous/Asynchronous Transmitter and Receiver. Data can be communicated synchronously or asynchronously. It is a serial port to which the Xbee module is connected for transmission of data and can accommodate full duplex communication as two buffers/registers are available to handle serial data. One is the TXREG which holds character data to be transmitted and the other is the RCREG which holds received data. Flags are used to signify presence of data in these registers.

c) Smoke Detector: This is a digital sensor which signifies the presence of smoke in its vicinity. It has been used as a replacement for fire detector. The sensitivity of these smoke sensors vary and for these prototype implementation a GH-312 sensor has been used. Its output is high in the presence of smoke and low when no smoke is present. It can function with input voltages of between 9 and 20V.

d) Temperature Sensor: The LM35 is used as a temperature sensor. This is an anlogue sensor and thus is connected to the analogue to digital conversion channel. Its output increases by 10mV for every 1^{o}C rise in temperature and can measure temperatures within a range of -55^{o}C to 150^{o}C. It operates with input voltages between 4 and 30V. For our application, the sensor is used to measure day and night atmospheric temperatures.

e) Humidity Sensor: The DHT11 is used for humidity sensing application. DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. The humidity measurement component is resistive in nature and can connect to fast 8 bit microcontrollers providing excellent quality, fast response, anti-interference capability and cost effectiveness. It requires a power supply of 3 to 5.5V. The overall communication process is shown in Figure 5.

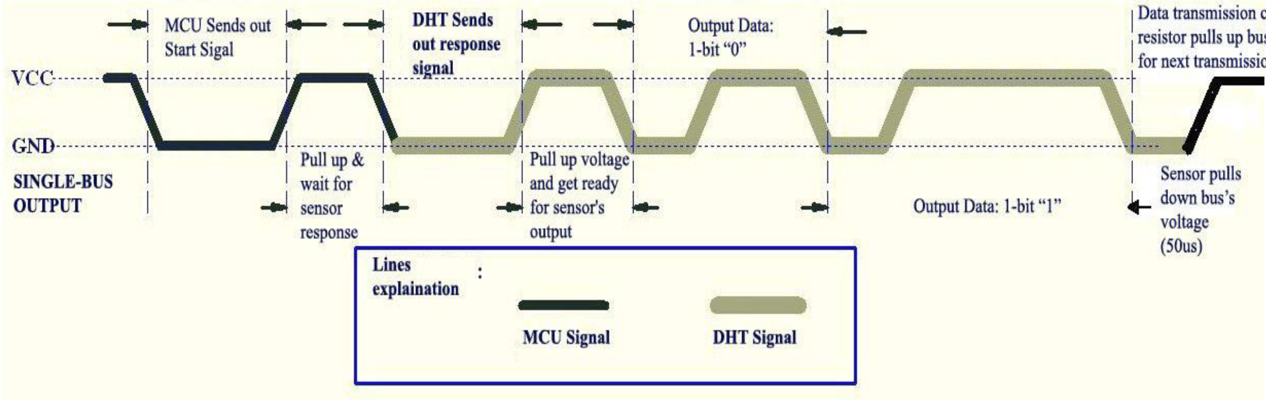

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Figure 5: Overall Communication Process of DHT11

Microcontroller sends a START signal and this results in DHT11 to running mode from low power consumption mode and waits for microcontroller to complete start signal. After this, the sensor sends a 40-bit data signal which contains the humidity value and the temperature value. The user can choose which data to consider. The DHT will only give response if a start signal has been received from microcontroller. To send another set of data the microcontroller must again send start signal. Thus it is like, the microcontroller requests data from sensor device.

5. Testing and Results

The Master node was implemented using an LPC2148 development board from Nex-Robotics and peripheral hardware such as the 20x4 LCD and GSM modem were attached to the board. The Sensor node was built by the author using the PIC microcontroller and associated hardware. A 20MHz oscillator was used to increase processing speed. The system was tested and it functioned according to expectations. Figure 6 and 7 illustrate snapshots for the hardware circuit for the Master node (Figure 6) and Sensor node (Figure 7).

Figure 6: Master Node side simulation hardware

The LCD display shows the current time as well as the maximum and minimum temperatures recorded for the day. The mobile user can request data and also send control commands and directly communicates with the master node through a GSM modem. The master node then provides data if it is locally stored in the master node or requests data from sensor node if current values are needed, e.g. current temperature or humidity values. Figure 8 shows a message received by the mobile user after requesting the max and min temperatures recorded for the day. The max and min temperatures and the time at which they are detected are provided to the mobile user.

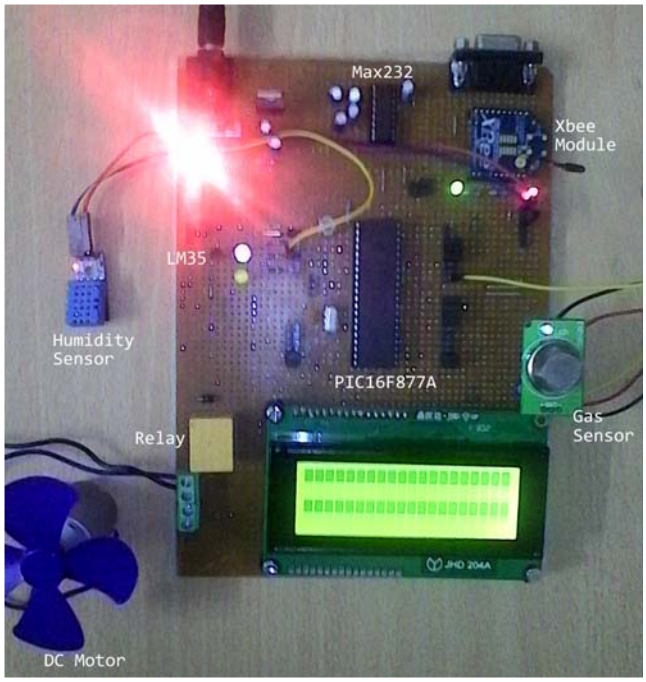

Figure 7: Sensor node and associated sensors

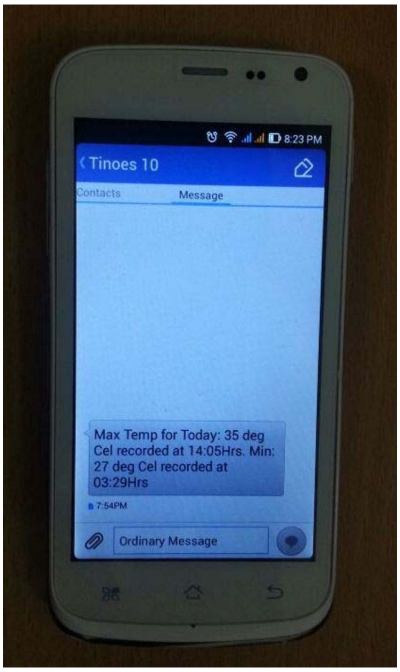

Figure 8: Mobile User Received data

6. Conclusion

The proposed system was a success as it illustrated the proposed concept. Thus as a way of expansion on the system a PC can be used as a server/database such that parameter values can be stored for a larger number of days since the system illustrated here only managed to store values for two consecutive days. The inclusion of a database can be done using even office access or any other database utility and a graphical user interface created using C# to easily access the database.

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