DESIGN OF LM4F120H5QR BASED NODE FOR WIRELESS SENSOR NETWORK TO MONITOR ENVIRONMENTAL PARAMETERS OF POLYHOUSE

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ABSTRACT
Wireless Sensor Network (WSN) is an innovative field, exhibiting interdisciplinary relevance. For polyhouse agriculture, the management of environmental, as well as soil parameters, data to ensure sustainable plant growth, is the need of hour, for which WSN provides suitable solution. With the view to ensure Precision Agriculture (PA), a wireless sensor network is established, wherein the wireless sensor nodes play significant role. To ensure great reliability and flexibility the nodes are designed, wherein ARM microcontroller, LM4F120H5QR is deployed along with transceiver RF module, Chipcon CC2520. The nodes are dedicatedly designed for two parameters, the humidity and the environmental temperature. The smart sensors module, SY-HS-220 for humidity and LM-35 for temperature are deployed. Analog part of the hardware is designed about high input impedance CMOS operational amplifiers. The hardware as well as software of present embedded systems is co-developed to ensure synchronization. The nodes are calibrated to the scientific units. Results of the regression process reveal good linearity for humidity and temperature as well. Empirical relations are deployed in the firmware to achieve continuous monitor of said parameters. The sensor nodes collaboratively collect the data and disseminate towards smart Base Station (BS) in star topology. The WSN is established in ISM band at 2.4 GHz frequency. Employing VB environment the GUI is designed to display Site Specific Data. The results of implementation are interpreted in this paper.

KEYWORDS: *Wireless Sensor Networks, CC2520, ARM Microcontroller, Smart Base Station, precision agriculture, Humidity.*

I. INTRODUCTION

The greenhouse agriculture is emerging field, wherein the crops are cultivated in controlled environment. Precision agriculture is the kind of agriculture, wherein both environmental as well as soil parameters, depicting the site specific variability (SSV) are monitored [1-5][38]. To ensure this site specific data management, the wireless sensor network is the suitable solution. Wireless sensor network is a systematic organization of nodes routed in co-operative manner [6-11]. Each node has a processing unit, memory, RF transceiver, power source and array of sensors as well. The node communicates wirelessly and self organize after being deployed in an ad hoc network. The WSN realizes the deployment of IEEE 802.15.4 standards of wireless communication. The Zigbee technology is playing vital role in establishment of WSN for dedicated applications. Currently, wireless sensor networks are widely deployed in diverse areas. It is expected that, within few years the world may be connected with wireless sensor network and provides accession with the internet, to realize the concept of Internet of Things (IOT). In establishment of WSN, the nodes are autonomously operating at remote places. Therefore, the minimizing of power consumption is one of the key issues [12]. Therefore, precise and low power nodes are required for development of wireless sensor network. In facts, the nodes can be designed with microcontrollers of promising features. The features of the nodes vary with the designing

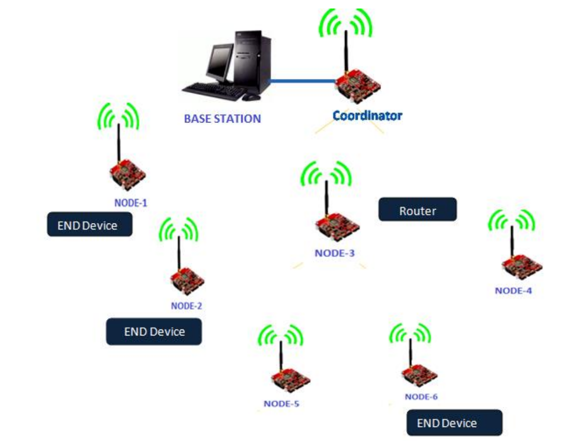

Figure.1 Architecture of Wireless Sensor Network

issues of hardware and firmware. Therefore, designing of nodes of prominent features is one of the challenging jobs. Therefore, many researchers are exhibiting significant interest in developing wireless sensor node. The pH of the soil essentially decides the quality of the soil. Therefore, measurement of the pH of the soil and online monitoring of the same precisely is the need of hour. Traditionally, the pH of the soil is measured in the chemical laboratories. Using pH sensitive Field Effect Transistor (IFET), Shneghal et, al have proposed to design the nodes to monitor the nutrient of the soil [13]. The wireless sensor network designed and implemented for monitoring of environmental parameters of high-tech polyhouse wherein AVR ATmega8L microcontroller is used as processing unit, is presented elsewhere[14]. In health monitoring, Heart sound stethoscope, is primitive stage to diagnosis the disease. Therefore, Patil et, al [15] have designed an electronic stethoscope, based on an embedded processor, wherein wireless transmission is ensured using zigbee. The Mancuso and Bustaffa [16] have carried out respective work for tomato greenhouse in the south of Italy. They used sensicast devices for the temperature, relative humidity and soil temperature measurement with wireless sensor network. The information regarding these parameters is demonstrated on the mobile phones either through message or GPRS. The Mancuso et, al have established the WSN over 20 × 50 meters polyhouse wherein tomato is cultivated. They deployed six nodes and positioned systemically in the form of array. Recently, a wireless sensor network is also designed and employed for air pollution monitoring system [17]. The greenhouse parameters such as temperature, humidity, light intensity, CO_2 gas concentration etc, should be essentially monitor and control [18]. The wireless sensor network provides the dynamic and flexible structure for the transmission of data acquired from the end devices. Therefore, WSN is most suitable for site specific data management. On extensive study, it is found that, the reliability of wireless sensor networks significantly depends upon the salient features of the sensor nodes. Therefore, the sensor nodes of prominent features have been designed and presented in this paper. The paper is organized into three sections, section-I hardware of the Wireless Sensor Node are elaborated, section-II gives software part of the work is discussed and in section-III the implementation of the wireless sensor node and results are discussed.

II. DESIGNING OF WIRELESS SENSOR NODE

The LM4F120H5QR microcontroller is used to design the wireless sensor node. The designed system senses the greenhouse parameters and transmits the same to the base station. To realize the wireless communication the zigbee technology is deployed. It is also found that there are verities of RF modules operating within the IEEE 802.15.4 standards. The present system is designed about the RF transceiver Chipcon make model CC2520. The PHY and MAC layers of zigbee stack [37] are deployed as per IEEE standards. However, it is attempted reconfigure the application and network layers. According to architecture of wireless sensor network depicted in figure 1, it is an establishment of wireless sensor nodes and the base station. The nodes are wirelessly routed, through star networking topology, with the coordinator. According to the task allotted, the nodes of WSN are of three types such as END device, Router and the Coordinator. The END device is the reduced functionality device (RFD) and it is battery operated device. The router is Full Function device (FFD), communicating with all sensor nodes. The coordinator is only one in a network that establishes link with the sensor nodes and router as well. It stores the information of a network also. It is known that, the sensor nodes realize the deployment of an embedded technology, wherein both hardware and software are co-designed. Present communication emphasizes the design of sensor nodes for WSN for monitoring of typical environmental parameters. Both hardware and firmware are co designed for both sensor nodes and the base station as well. The design issues are presented in this paper through following points.

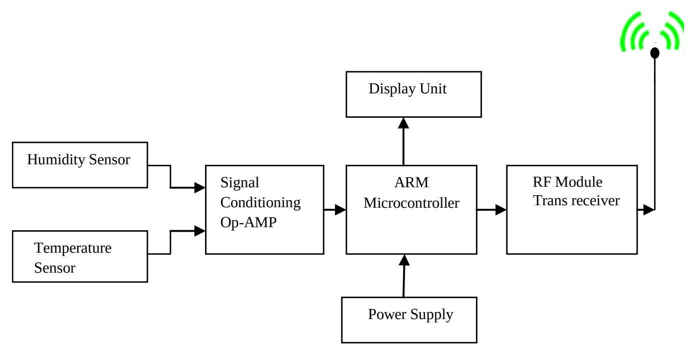

Figure.2 Block Diagram of Wireless Sensor Node (END Device)

A) Designing of Wireless Sensor Node.

B) Designing of smart Base Station.

2.A. Designing of Wireless Sensor Node:

It is known that, the wireless sensor node is the realization of embedded design, which comprises hardware as well as software with equal significance. Both hardware and software required for this ARM based wireless sensor node is designed and presented subsequently as hardware of wireless sensor node and firmware for wireless sensor node.

2. A.i) Hardware of Wireless Sensor Node:

With the view to monitor the polyhouse parameters the wireless sensor nodes are designed, deploying which wireless sensor network is established. The wireless sensor node ensures embedded design. The hardware of the present sensor node is depicted, in figure 2 as a block diagram. As shown in figure 2, the wireless sensor node consists of the blocks such as an array of smart sensors, signal conditioning circuit, ARM microcontroller, display unit, power supply, RF module CC2520 etc. The system is designed to monitor typical polyhouse parameters such as relative humidity and temperature. An electrical signal produce by the sensors are conditioned. The signal conditioning circuit is wired about CMOS operational amplifier MCP606. On chip ADC of the ARM microcontroller LM4F120H5QR is deployed for data conversion. Microcontroller performs the task of data processing and the RF module CC2520 is deployed to ensure wireless communication. The RF module CC2520 transceiver has SPI interface capabilities. Therefore, it is interfaced with microcontroller in SPI configuration. The RF module is configured to support IEEE 802.15.4 standard. The schematic of the circuit, designed to ensure wireless sensor node is shown in figure.3. The wireless sensor node consits of an array of sensors such as humidity sensor SY-HS-220 and temperature sensor LM-35. These sensors are highly reliable and produce D.C emf, which is directly proportional to the actual values of said parameters. In fact, these signals depict the environmental condition of the polyhouse. To emphasize the facts of analog design,the signals are strengthens by employing CMOS based operational amplifier MCP606.An analog output of the operational amplifiers is given to the ARM microcontroller LM4F120H5QR

and for further processing, it is subjected serially to the RF module CC2520 transreciver. The analog as well as digital part of present embedded system is designed and the designing issues are discussed subsequently through following points.

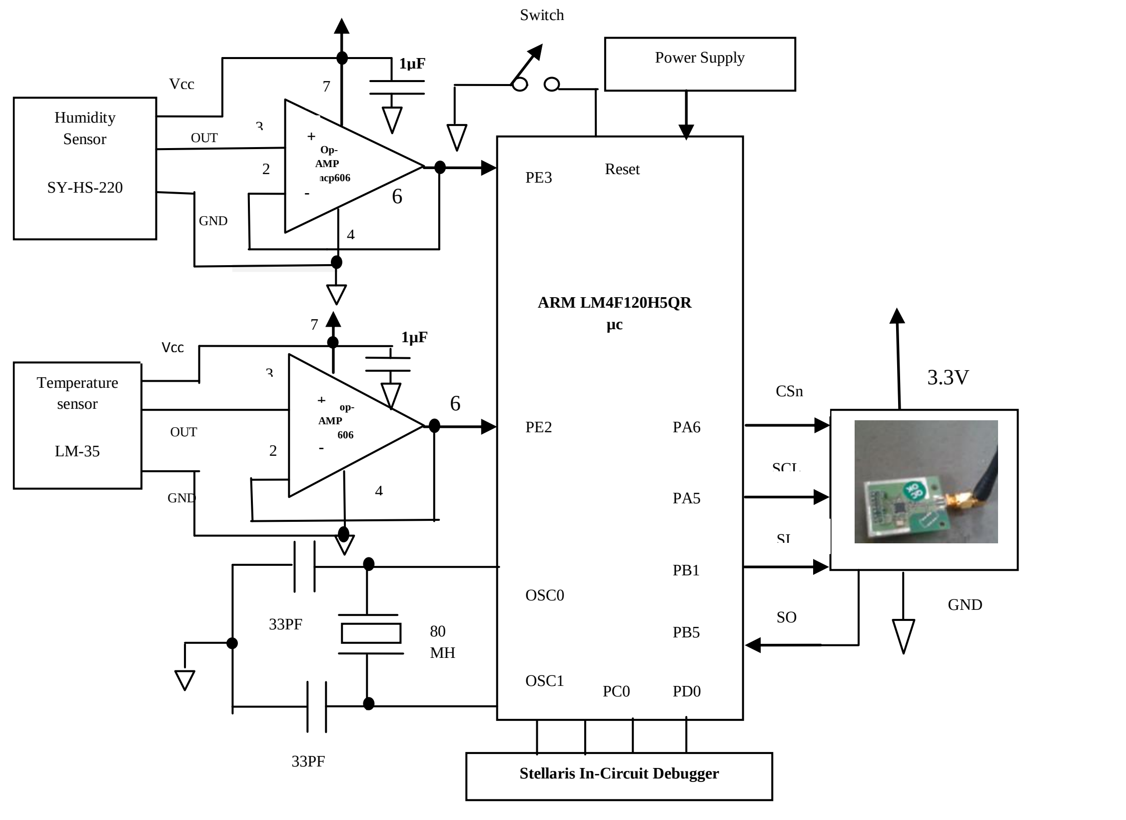

Figure.3 Schematic of Wireless Sensor Node

a) An Array of Sensors:

Present system realizes the design of wireless sensor node for monitoring of environmental parameters, the humidity and temperature, in particular. For this purpose the deployment of sensors of promising feature is essential. Therefore, as discussed earlier the smart sensor module SY-HS-220 and LM-35 are deployed as sensors. The details regarding these sensors are discussed.

b) Humidity Sensor [SY-HS-220]

The humidity is the major parameter as it decides the growth of the plant. The humidity specifies an amount of water molecules present in the air of polyhouse environment. The humidity sensor(SY-HS-220) is used to measure the relative humidity. Figure.4 shows photograph of an SY-HS-220 humidity sensor. The SY-HS-220 module consist of sensing unit along with other signal conditioning part of the circuit, such as thermistor for temperature compensastion. The SY-HS-220 sensor is highly precise and reliable. It provides DC output voltage depending upon humidity of the region in RH%. It works with +5V power supply and current consumption is less than 3.0 mA. The operation range of humidity is 30-90% RH which is sufficient for the system under investigation. The operating temprature range is 0-60 ^{0}C. Moreover, at a typical environmental condition, at 25^{0}C and for 60 % RH the sensor module provides an emf of 1980mV [19]. Accuracy of this sensor +/-5% RH. It has 3-pins; pin B is analog ground; pin W provides DC output voltage and R is dedicated for power supply [19]. The output voltage of humidity sensor (V_H) is given to signal conditional circuit. The output linearly varies with the relative humidity, which would significantly help to calibrate the system more precisely.

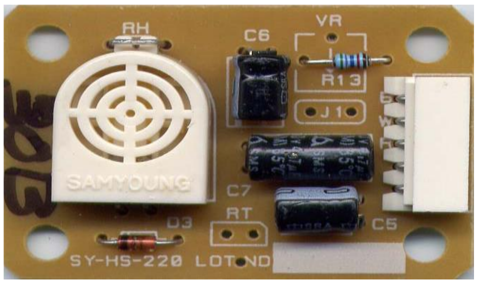

Figure.4 The Humidity Sensor SY-HS-220

C) Temperature Sensor LM-35

The temperature also affects the growth of the plant. Therefore, it is essential to monitor the thermal status of the polyhouse environment. The LM-35 series is of precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the temperature in degree Celsius. On investigation of its structural details, it is found that the LM-35 sensor is most suitable sensor for present design. The LM-35 provides typical accuracies of +/-0.25ºC at room temperature and +/- 0.75ºC over a full -55^{0}C to +150 ºC temperature range [20]. The LM-35 is available in hermetic TO-92 plastic transistor package. The current consumption is less than 60µA. The change in emf produced by the sensor is extracted and given to further processing. The temperature coefficient α exhibited by this sensor is 10 mV/^{0}C [20].

d) Signal Conditioning:

As discussed earlier, both sensors are providing dc emf, which reveals linearity with respect to the variation in the parameters values [33-36]. To realize the need of measuring instrumentation, the signal conditioning is in envitable. The signals under investigation are connected to the operational amplifiers, wired as signal conditioner. As depicted in figure 3, the signal conditioning circuit is wired about CMOS operational amplifier MCP606, which exhibits rail to rail characteristics for both input and output purpose [21]. It suitably provides sinking and sourcing current at precise level. The CMOS operational amplifier is configured as a buffer which helps to ensure isolation of the sensors. The features of this family of operational amplifier are well suited for single supply precision, high impedance and battery powered applications. The signals are conditioned and then subjected to further process of digitization and calibration.

e) Computing Unit:

On extensive study of architecture of wireless sensor node, it is realized that the sensor comprises a computing unit with smart features. Essentially, limited computing capability is the key feature of node. A computing unit of present node is designed about LM4F120H5QR microcontroller. Figure 5 shows pin diagram of this microcontroller. The Data Acquisition System (DAS) is most important part of an embedded system design.

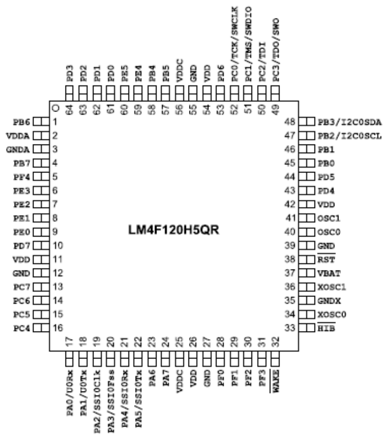

Figure.5 Pin Diagram of LM4F120H5QR

In fact, DAS consists of devices such as multiplexer, demultiplexer, FIFO register, ADC, processing unit [22] etc. Now days and the embedded processor is coming with advanced features. Microcontrollers from ARM families are becoming more and more pervasive, because of their commendable features. Deploying LPC2148 series the designing of an embedded system for dedicated application is reported by various investigators [30-32]. The ARM microcontroller LM4F120H5QR is having promising on-chip features. It`s architecture is developed about ARM Cortex-M4 processing core. An analog to digital converter should be essentially deployed in measurement instrumentation, which converts a continuous time domain analog voltage into a discrete digital number. The Texas Instruments Stellaris family based ARM LM4F120H5QR has two analog to digital converter (ADC) such as ADC0 and ADC1. Its ADC modules are featured with 12-bit resolution and supports 12 – input channels. Availability of such smart on-chip data converters reveals, mixed signal kind of philosophy. On extensive study of architecture of the microcontroller it is found that it has on chip temperature sensor as well. Each ADC module contains four programmable sequencers allowing the sampling of multiple analog input sources without controller intervention. Each sample sequencer provides flexible programming with fully configurable input source, trigger events, and interrupt generation and sequencer priority. The trigger source for ADC0 and ADC1 can be independent configured. Moreover, two ADC modules may be operated from the same trigger source and on the same or different inputs. The sampling control and data capture is handled by on chip sample sequencers. All of the sequencers are identical in implementation. In present design, the sample sequencer ‘0’ (SS0) is employed. It is also found that, the register of FIFO type is associated with the sample sequencer. The sample sequencer is capturing 4-samples and allowed to hold in the FIFO register of 4 byte depth. Present microcontroller exhibits 32-bit processing capacity. Therefore, the FIFO register are also 32-bit word. In present implementation, each FIFO register, out of 32-bit word, the lower 12-bits are containing the conversion result [22]. The sample sequencer ‘0’ (SS0) has 4-FIFO’s. First FIFO register stores humidity related results, which are coming from pin AIN0 (PE3). Moreover, second, FIFO register stores temperature dependant results, which are obtained from pin AIN1 (PE2). Each sample is defined by the bit fields in the ADC Sample Sequence Input Multiplexer Select (ADCSSMUXn) and ADC Sample Sequence Control (ADCSSCTLn) registers. The ADCSSMUXn fields select the input pin, while the ADCSSCTLn field selects the sample control bits corresponding to parameters. Sample sequencer are enabled by setting the respective ASENn bit in the ADC Active Sample Sequencer (ADCACTSS) register and it should be configured before being enabled. Sampling is then initiated by setting the SSn bit in the ADC Processor Sample Sequencer Initiate (ADCPSSI) Register. After a sample sequencer completes execution, the conversion result can be popped up from the ADC Sample Sequence Result FIFO (ADCSSFIFOn) registers. The ADC0 uses the internal reference voltage 3.3V. Most of the ADC logic runs at the ADC clock rate of 16 MHz. On chip prescalar are configured for 16 MHz operation. ADC modules interrupt signal are controlled by the state of the MASK bits in the ADC Internal Mask (ADCIM) register. Interrupt Status can be viewed in the ADC Interrupt Status and Clear (ADCISC) register, which show active interrupts that are enabled by the ADCIM register. Thus, the data converters are configured to ensure analog to digital conversion. The digitized data is used for further computation. The Stellaris family Cortex-M4-Based LM4F120H5QR microcontrollers depicts top performance and advanced integrability. It is most suitable for cost effective applications such as handheld smart devices, such as medical instrumentation, fire and security, smart energy, smart grid solution etc. The LM4F120H5QR microcontroller is designed arround an ARM cortex-M4 processor core. The ARM Cortex-M4 provides the core for a high-performance, low-cost platform that meets the needs of minimal memory implementation, reduced pin count and low power consumption and it is for small footprint embedded applcations. It is operated on 80 MHz however the code density ensures Thumb-2 mixed 16/32-bit instruction set architecture (ISA). The salient features of this microcontroller are nested vectored interrupt controller, memory protection unit, floating point architecture, on-chip memories (32-KB SRAM, 256KB flash memory, 2KB EEPROM) serial communication peripherals (CAN,USB 2.0, 8-UART, I2C), configurable digital cores(six 32-bit timers, six 64-bit timers), low power battery backed hibernation module, upto 43-GPIO`s, two 12-bit ADC with 12 analog input channels. Therefore, this microcontroller is employed to design wireless sensor node for monitoring of polyhouse environment parameters.

f) RF Module CC2520:

To realize the design of wireless sensor node, along with sensing and processing unit, the RF communication unit is equally important. It is known that, a variety of RF modules are available to ensure wireless data communication. The present design employ CC2520 RF module. The CC2520 transceiver [23] is Texas Instruments second generation, RF module, operated according to Zigbee

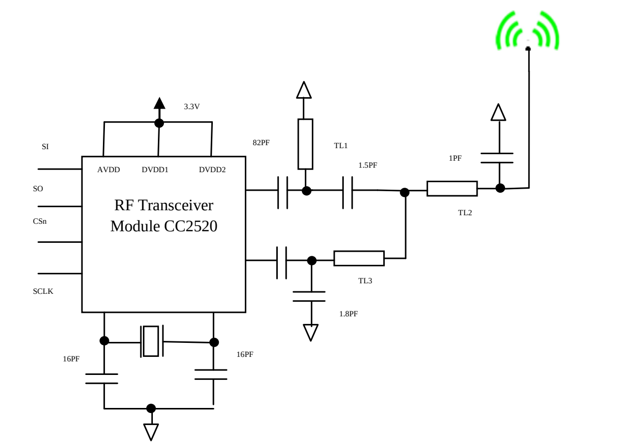

Figure.6 Schematic of RF Transreceiver Module CC2520

IEEE 802.15.4 standards [26] within the 2.4 GHz unlicensed ISM band. The figure 6 depicts schematic of the RF module CC2520. This chip enables industrial grade applications by offering up to 125^{0}C and low voltage operation. In addition, CC2520 provides extensive hardware support for frame handling, data buffering, burst transmission, data encryption, data authentication, clear channel assessment etc. The RF module CC2520 transceiver has following features:

- 250kbps data rate.
- O-QPSK with half sine pure hoping modulation.
- Very low power consumption.
- 3-flexible power modes
- Low supply voltage (1.8V-3.8V)
- 4-wire SPI
- Serial clock up to 8 MHz.
- IEEE 802.15.4 MAC hardware support.

According to architecture of this RF module, it is a 28 pin RF module and it provides SPI interface. The minimum pin required to interface with SPI are SCLK, SO, SI, CSn. As discussed earlier, an analog and digital section of present node produces the data related to respective parameter values. It is then given to the RF module CC2520 for transmission. The CC2520 RF module receives the parameter values from microcontroller. The CC2520 uses IEEE 802.15.4 standard packet format for transmitting the data.

2. A.ii) Firmware for Wireless Sensor Node:

The software used in sensor node (END Device) developed by using Code Composer Studio (CCS) Version 5.0 IDE in embedded 'C' environment. In this IDE various software modules are developed for monitoring the environmental parameters.

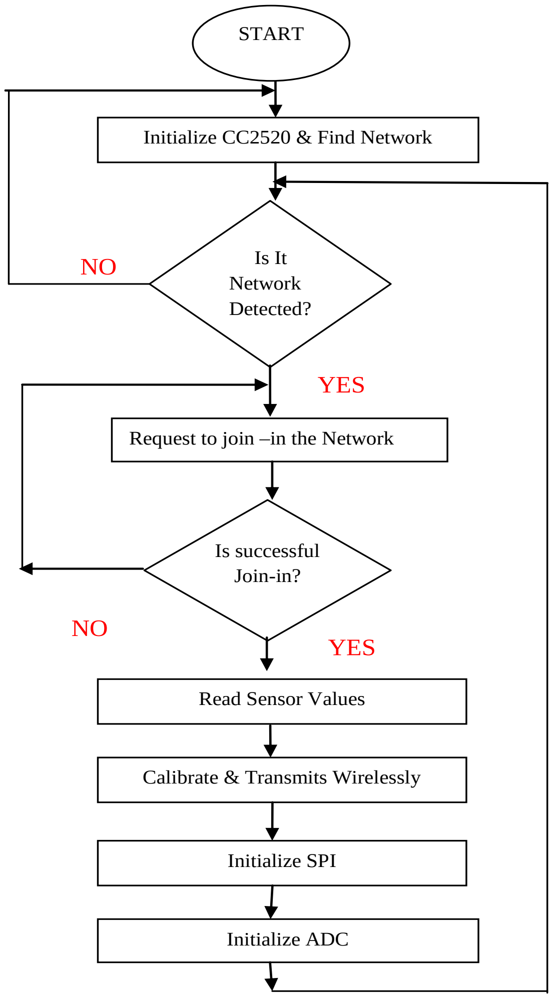

Figure.7 Design Flow of Sensor Node

The figure 7 shows the flow chart of the firmware. As depicted in figure 7, in the beginning, the RF module is initialized and allowed to search the network. It operates in polling mode. On availability of the network, immediate it joins the network. Now the RF module is linked into the network. Meanwhile, the processing unit, microcontroller, provides the digital data proportional to the parameter values. An empirical expression obtained from the process of calibration are deployed in the firmware continues execution of these expressions the firmware produces the values of the parameters, under investigation, in real units. Serial communication module initializes the SPI module and then transmits the data in specific word format towards the coordinator node. Thus, the wireless sensor nodes are designed for realization of wireless sensor network.

2. B) Base Station:

According to architecture of the WSN, the base station is rather equally important. It comprises co-ordinator node and the computer system required for processing as well as demonstration of the data.

2. B.i) Designing of Base Station:

The schematic of the base station is depicted in figure 8. As shown in figure 8, the co-ordinator node is designed. It is again realization of embedded design. Therefore, it essentially needs both hardware and software. The co-ordinator node is also designed about ARM LM4F120H5QR microcontroller and the design is almost identical with that of end device. Therefore, the discussion on designing issues of the hardware of the co-ordinator node is similar to that of sensor node. Moreover, any sensor node can also be configured as the co-ordinator.

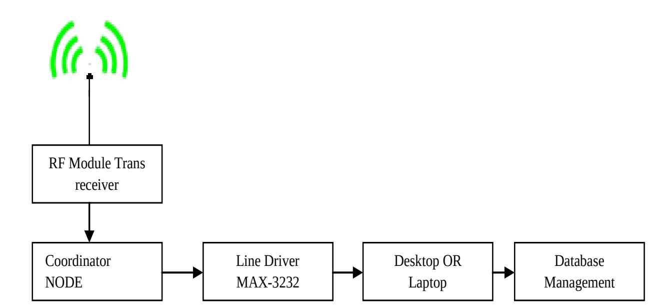

Figure.8.Block Diagram of Base Station with Coordinator

Moreover, embedded firmware is also designed and ported into the target device. As shown in figure 8, the co-ordinator is connected to laptop or desktop through serial interfaced. An UART is used to ensure interfacing of co-ordinator to the computers. The coordinator is interfaced with PC or desktop through the line driver MAX3232. On the PC a Site Specific Data Monitoring (SSDM) Graphics User Interface (GUI) is designed and described at next article. Thus, smart base station is designed and configured to realize the establishment of the wireless sensor network.

2. B.ii) Graphics User Interface for Base Station:

The Graphics User Interface (GUI) is designed in Visual Basic (VB 6.0), environment to facilitate the base station of wireless sensor network (WSN). The wireless sensor network incorporates the Base Station (BS) to monitor the distributed data regarding environment parameters [25-27]. As per the architecture of the wireless sensor network (WSN), the nodes have been designed and routed by ensuring Zigbee technology [28]. The node collects and disseminates the site specific data towards the base station. Moreover, the present design is dedicated for precision agriculture. Therefore, the parameters values should be demonstrated in user's friendly format. For this purpose, the graphical demonstration of data is always suitable [29]. To facilitate the graphical presentation of data, the design of GUI is needed. To facilitate the fundamental needs of the base station, smart Graphical User Interface (GUI) is designed and implemented which is shows in figure 9. The coordinator node is interfaced to the serial port of the computer. Immediately, the GUI act upon the serial port and read data from serial port. The data is in typical frame. Therefore, the GUI disassembles the packet and isolates the environment parameter values along with respective headers. The parameter values, humidity and temperature are extracted and displayed into respective windows. The windows are continuously updated with the recent data. Typically, for present WSN 8 nodes are routed. Therefore, 8 windows are created to display parameter values of respective nodes. Moreover, instantaneous values of the parameters are also stored, in real time, into the database created for this dedicated purpose.

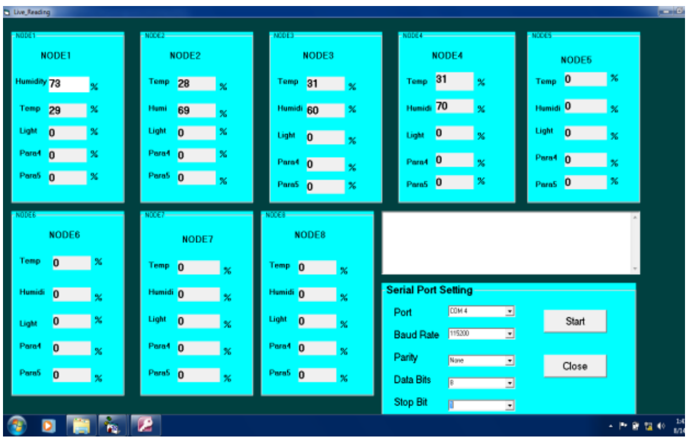

Figure.9 Snapshot of VB Based GUI for Live Monitoring

III. Implementation of Wireless Sensor Node for Wireless Sensor Network

The two parameters, humidity and temperature are considered for present design. In fact the present system realizes measurement instrumentation. Therefore, the designer has to carry out the calibration of the system to the standard unit. Therefore, before implementation, the nodes (END Devices) are subjected to the process of calibration.

3.A.i) Calibration of the Nodes to the Humidity in %RH :

It is known that, sensor module provides an output emf (V_H) proportional to the relative humidity (H) in (RH %). Therefore, the emf values shown by the system under investigations are recorded against variable humidity. A standard humidity chamber is employed for application of Humidity. The experimental arrangement is shown in figure 10. The graph of observed emf (V_H) plotted against

Figure.10 Experimental arrangement for calibration of the system under investigation.

humidity (H) in %RH is shown in figure 11. The graph depicts linear variation. On implementation of regression process an empirical relation, equation 1, is obtained.

$$V_H = 0.024H + 0.697 \qquad \ldots(1)$$

The humidity dependant voltage (V_H) is recorded in volts. Therefore, the slope of the graph α_H = 0.024, represents humidity coefficient of the system under investigation. Equation 1, also reveals the

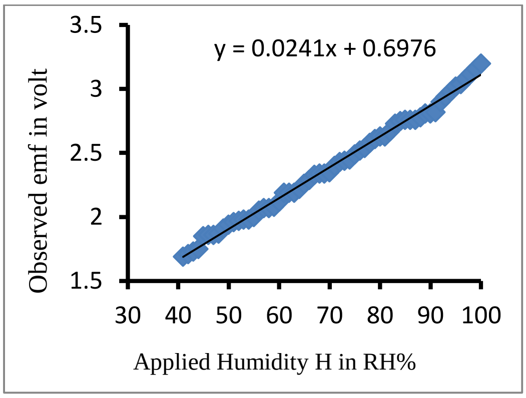

Figure.11 Graph of observed emf(V_H) against applied Humidity (H) in %RH

Table.1 Humidity shown by the System under Investigation and Gayatri Scientific Chamber

Humidity (%RH) Shown By	
Standard Humidity meter	System under investigation
30	29.3
35	34.3
40	39.3
45	44.5
50	49.3
55	55.0
60	60.0
65	64.6
70	70.2
75	75.8
80	80.8
85	86.5
90	93.5

offset emf of about 0.697 Volt (697mV). Experiment is carried out at room temperature (25^0C) and at environmental humidity (%30RH). According to data sheet of SY-HS-220, this emf should be

1980mV [19]. Deviation in the voltage may be due to the fact that, in datasheet of SY-HS-220 an emf (1980 mV) is given for 60% RH environmental humidity and at 25^{0}C temperature. However, for present system the range of investigation begins from 30%RH. Therefore, the observed offset emf is less than that of mentioned in the datasheet of the humidity sensor. Expression 1 can be represented as

$$H = [(V_H – 0.697) / 0.024] \qquad …(2)$$

This equation is employed in the firmware which causes to produce continuous values of humidity in RH% unit. The system is also standardized with standard humidity meter. For standardization of the system, humidity from 30%RH to 90 %RH is applied by employing standard humidity chamber, Gayatri Scientific (India). Humidity values shown by the system are presented in table 1. From table 1, it can be said that the humidity values shown by the system under investigation depict close agreement with that of given by standard humidity meter. This reveals preciseness in the designing of analog as well as digital part of the wireless sensor node.

3. A.ii) Calibration of the Node to the Temperature in Degree Celsius:

It is known that, the sensor unit comprises LM 35 as a temperature sensor. It is semiconductor, monolithic sensor and provides an output emf (V_t) directly proportional to the environment temperature, in degree Celsius. The temperature coefficient is □$_t$ is 10mV/^{0}C [20]. Therefore, emf values shown by the system under investigation are recorded against various temperatures from 25^{0}C to 100^{0}C. The graph, of observed emf (V_t) plotted against temperature, is shown in figure 12. The graph depicts linear variation. On implementation of regression process, an empirical relation, equation 3, is obtained.

$$V_t = 10\ t \qquad …(3)$$

On inspection of equation 3, it is found that the temperature coefficient of the system α_t is 10mV/^{0}C, as expected. Therefore, the equation,

$$\text{Temperature } (t) = V_t / 10 \qquad …(4)$$

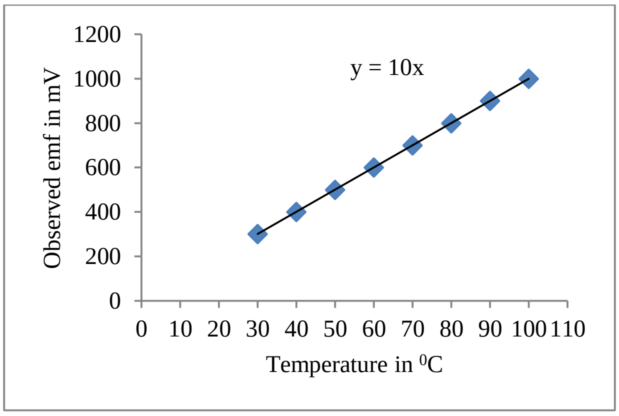

Figure.12 Graph of observed emf V_t (mV) against applied temperature t (^{0}C)

Table.2 Temperature Shown by the System under Investigation and Standard Thermometer.

Temperature (^{0}C) Shown By	
Standard Thermometer	System under investigation
30	30.0
35	35.0
40	40.0
45	45.0
50	50.0
55	55.0
60	59.0
65	63.5
70	68.2
75	71.9
80	83.2
85	84.3
90	86.8

is employed in the firmware which causes to produce continuous values of temperature in degree centigrade unit. The system is also standardized with standard thermometer. The table 2 shows the temperature values shown by the system.

3.B) Result and Discussion:

The figure 14 shows the experimental setup of wireless sensor node, which is also known as END device. The END device disseminates the dada packet to the base station. The figure 13 shows the Base Station continuously presenting the values of humidity and temperature of the polyhouse environment.

At the base station co-ordinator collects disseminated data packet from End devices and displayed in Graphics User Interface (GUI). As shown in figure 14, the sensor node, referred as End device, is sensing the physical parameters. Figure 14 depicts the implementation of typical wireless sensor node. It collects the values of the humidity and temperature of the location at which it has been deployed. It is found that, values of the parameters vary from site to site. This could be attributed to the fact that, the parameters reveals Site Specific Variability (SSV). The parameters values sensed by the respective node and collected at the base station are recorded with real time. Typical values of humidity and temperature, recorded against time are presented in the table 3. On inspection of the table 3, it can be said that the range of variation of humidity and temperature are constant at that location. Instantaneous variation in the values of these parameters realizes environmental changes. This data regarding environmental variation is most suitable for precision agriculturists for further prediction and crop management.

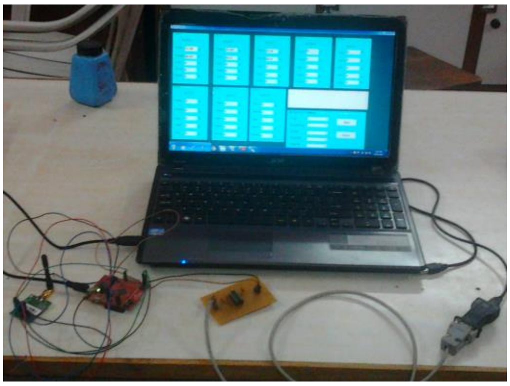

Figure.13 The Base Station continuously presenting the values of humidity and temperature of the polyhouse Environment.

Figure.14 Implementation of typical wireless Sensor node within the polyhouse.

Table 3 : Parameter values , humidity and temperature, shown by the present WSN deployed at the polyhouse environment.

Time in Minute	Humidity(%RH) shown by the system under investigation for Polyhouse	Temperature (^{0}C)shown by the system under investigation for Polyhouse
	29.22	60.05
	29.21	60.11
	29.32	60.12
	29.32	60.25
	29.03	60.19
	29.12	60.19
	29.25	60.20
	30.01	61.06
	30.12	61.07
	30.22	61.18
	30.23	61.21
	30.32	61.29
	30.65	61.31

IV. CONCLUSION

Emphasizing inevitable features of the ARM microcontroller, LM4F120H5QR, and to enhance the characteristics of Wireless Sensor Network, a Wireless Sensor Node is designed, wherein CC2520 RF module is used ensure wireless communication. Wireless sensor node is the realization of embedded technology. Therefore, both hardware and firmware is co-designed. Based on VB environment a smart GUI is also developed and implemented to enhance the features of the base Station. The nodes are standardized. Results of standardization support the reliability and preciseness in the design and calibration process. Instantaneous values of the parameters depict site specific variability. The Wireless Sensor Network proves its suitability for such SSV data management.

V. FUTURE WORK

After implementing the wireless sensor network for polyhouse our intension is to implement the wireless sensor network for monitoring of industrial parameters and also try to implement the different types of protocol for WSN to reduce the power consumption of the network so it can helps to increase the life of the network.

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