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ARM Microcontroller Based Wireless Sensor Network to Monitor Environmental Parameters of Textile Industry

S. V. Chavan*, S. K. Tilekar, P. V. Mane-Deshmukh and B. P. Ladgaonkar

Post Graduate Department of Electronics, Shankarrao Mohite Mahavidyalaya, Akluj

Maharashtra, India

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Abstract: Indeed, Wireless Sensor Network (WSN) is an ubiquitous field, exhibiting wide application potential for electronic management of data of Site Specific and Temporal Variability (SSTV). Emphasizing real time monitoring of an indoor environment of textile industry, the WSN of five sensor nodes (SN) has been designed and by employing suitable wireless communication protocol, it is established to monitor relative humidity and environmental temperature of textile industry. The salient features of the SN decide reliability and preciseness of the WSN. Employing an embedded technology, the wireless sensors nodes have been designed, wherein ARM microcontroller, ARM LM4F120H5QR, is used as a core for computational task. To facilitate wireless networking the Zigbee technology is availed, wherein the transceiver modules, Xbee series-2, have been incorporated. Typically, two sensors, humidity sensor (SY-HS-220) and temperature sensor (LM35), are interfaced, with suitable analog electronics, to the Sensor Nodes. Present sensor nodes have designed to follow IEEE 802.15.4 standards. Being a measuring instrumentation, the sensor nodes have been scientifically calibrated to the real units and standardized with sophisticated instrument as well. The Refinement factors (R) are optimized and resulting empirical relations have been incorporated into the firmware. The parameter values shown by the sensor nodes and that of obtained from the standard instruments found close match. This reveals the reliability and accuracy in the co-design of hardware and firmware. Deploying an IDE X-CTU, the SN have been configured for dedicated responsibilities such as End Devices (ED), Coordinator (C) and Router (R). The Wireless Sensor Network under investigation, for realization of on-site implementation, is established in the indoor environment of textile industry. Instantaneous values of parameters are recorded, in real time, in the dedicated data base and demonstrated on smart GUI of the Base Station as well. Results of implementation support the deployment of present WSN for industrial applications.

Keywords- Wireless Sensor Network, Zigbee Technology, ARM Microcontroller, Environmental monitoring, Textile industries.

I. INTRODUCTION

Wireless sensor network (WSN) is an innovative technology and it has been proved its suitability for various sectors. It depicts an enormous potential for industrial and commercial applications [1-3]. The wireless sensor network is an establishment of systematically distributed sensor nodes, who have the capabilities of sensing as well as computation [4]. The nodes are autonomous and sense the information about various parameters within grid of defined area [5]. Each node solders the responsibility of its own grid. Therefore, the nodes interact with the physical world and collect site specific information at the base station [6]. Thus, the WSN is most suitable for collection of information spread over wide area. On intensive study, it is found that, the WSN is significantly used for precision agriculture [7], wherein, the parameters of spatio-temporal variations should be essentially monitored. The WSN also proved its suitability for monitoring transportation, environmental monitoring, forecasting, pollution monitoring, security, disaster management etc [8]. Moreover, it is most suitable for monitoring of industrial parameters. In industry various physico-chemical parameters are to be monitored. For monitoring of such parameters, at present, wired networks have been deployed by many industries. However, use of wired network has its own constraint due to hardware complexity and ultra high power consumption. Therefore, the paradigm shift from wired to wireless networking is realizing. Therefore, for monitoring of industrial parameters, the WSN can play commendable role.

In case of industry, various physico-chemical parameters such as temperature, pressure, humidity of environment, leakages of various gases, water quality, pollution due to industrial waste, pH of solution etc have to be monitored by sophisticated electronic system, wherein the centralized monitoring is emphasized. Such localized system could not collect the information of site specific variability. The wireless sensor network is most suitable technology to cater this need. Out of the above parameters, the temperature of the environment and humidity in the textile industrial environment are considered for present investigation. These parameters can be collected through the network of sensor nodes, wirelessly connected to each other and to the base station as well. According to standard architecture the node has a processing unit, memory unit, RF transceiver module, power source and an array of sensors as well. The sensor node communicates wirelessly and self organize after being deployed in an ad hoc network. The WSN realizes the deployment of IEEE 802.15.4[9, 10] standards of wireless communication. The Zigbee technology is playing major role in establishment of wireless sensor network for dedicated applications [11, 12]. To address the theme of IOT, the density of the nodes should be significantly more. Therefore, exact and low power sensor nodes are necessary for the development of wireless sensor network. In facts, the nodes can be designed with microcontrollers of promising features. The features of the sensor nodes vary with the designing issues of hardware and software. Therefore, designing of the nodes of prominent features is one of the challenging tasks. It is known that, the microcontrollers from ARM Cortex family show prominent features, which are highly suitable for embedded development. Moreover, the wireless sensor node realizes the design of embedded system. Therefore, deploying ARM Cortex M4 microcontroller, the nodes have been designed to monitor the textile industry parameters.

On extensive survey, it is found that, the humidity of the environment is playing commendable role on industrial processes. Particularly in case of paper and pulp making industries, it is essential to monitor and control the relative humidity at desired set point. Moreover, it is also found that, in textile industries humidity of the environment must be precisely controlled. The humidity is one of the major parameters which should be monitored and controlled in food industry and food storage plants as well. Humidity of the environment plays vital role on quality of the milk product manufactured in the dairy. In agro-based industries humidity of the environment matters on the quality as well as quantity of the products. In chemical industries and sophisticated laboratories, to favor typical reactions, the humidity of the environment should at controlled level. Humidity, relative concentration of water vapor in the air, depicts Site Specific Variability (SSV) [13]. Due to this, values of the relative humidity changes from site to site in given time domain. Therefore, the relative humidity depicts spatio-temporal variance. For collection of data of Site Specific Variability, implementation of WSN is most suitable solution. Therefore, emphasizing monitoring of relative humidity of industrial environment the WSN is developed. Keeping pace with the objectives of present research work, the SN is developed to monitor relative humidity of the industrial environment and designing issues are presented. Results of implementation are interpreted in this paper. Monitoring of relative humidity of an environment is need of the hour for many sectors. Therefore, the investigators have designed the WSN for monitoring of relative humidity and results have been reported. The Song et al [14] have designed wireless sensor network for monitoring and control of greenhouse environment. In this system the microcontroller from ATmega128L and radio module CC2530 from Texas Instrument are used to design sink node and sensor node for the wireless sensor network. The wireless sensor network designed and implemented by R. K. Prasad and S.R. Madkar [15-16] for data acquisition of multi-parameters like soil temperature, soil moisture and humidity. The system continuously monitors the parameter values at the base station and if it exceeds the specified limit, a message is sent to the farmer on its mobile through GSM network for controlling actions. Wireless sensor network designed and implemented for the indoor air quality monitoring by Jesus Lozano et al [17]. The developed system consists of a base station, which is connected to the internet and several autonomous nodes equipped with different sensors such as temperature, humidity and light intensity etc. B. Ramamurthy et al [18] have designed the low cost GSM based humidity monitoring for industrial applications. The presented system uses Global system for mobile communication (GSM) for the monitoring and control of humidity in industrial environment. They used humidity sensor module HSM-20G, as a computing unit ARM microcontroller LPC2148 and GSM Unit for communication. The Ji - Woong Lee et al [19] have designed the paprika greenhouse system (PGHS), which collects the paprika growth information and greenhouse information to control the paprika growth. For this purpose, the monitoring of the temperature of the environment is emphasized. The Yi – Jen Mon et al [20] have designed the wireless sensor network for indoor temperature monitoring through WSN wherein the sink node is facilitated with Smart LCD for temperature readout. Margaret Richardson et. al [21] have designed the wireless sensor network for monitoring high temperature of coalmine fire. In this system they developed the WS nodes (SN) about JN5139 microcontroller and following IEEE 802.15.4 standards the WSN was established. Chen et al [22] had developed WSN for industrial applications to monitor and control the temperature of the environment. It was the realization of relay assisted network. The introduced the novel concept of relay node. The sensor nodes (SN) perform the sensing the information about temperature of the environment. Moreover, the Relay Node (RN) ensures the actuation for controlling of the temperature. Thus from literature survey, it can be said that, the WSN is widely deployable for atomization in the industry. Therefore, many people are undertaking the research work on development of WSN for monitoring of industrial parameters. In this paper, results of design and implementation of WSN for monitoring of textile industrial parameters are interpreted.

II. DESIGNING OF WIRELESS SENSOR NODE

Following the basic architecture, the wireless sensor node is designed for textile industrial application for monitoring dedicated parameters. The LM4F120H5QR ARM microcontroller is used to develop the computing unit. Figure 1 shows the block diagram of hardware of the wireless sensor node. To realize the wireless communication the Zigbee technology is deployed. Present system is designed about the RF transceiver Xbee series-2 from DIGI International Inc. The PHY and MAC layers of zigbee stack [23], as per IEEE standards are configured. However, it is attempted to reconfigure the application and network layers. According to the block diagram depicted in figure 1, the signal conditioning circuits have been designed for each sensor. The nodes are developed for monitoring of environmental temperature and humidity of the textile industry. Each of the nodes is configured as End device, which allows to physically interacting with the measurand. Along with the nodes the co-ordinator is also designed and interfaced to the base station. All nodes and the co-ordinator are configured by using X-CTU IDE provided by Digi Corporation. The design issues are presented in this paper through following sections.

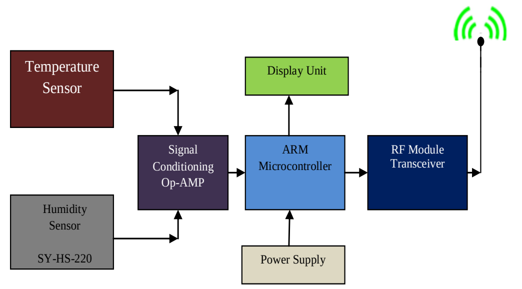


Figure.1 Block Diagram of Wireless Sensor Node (END Device)

A) Hardware of Wireless Sensor Node.
B) Firmware for Wireless Sensor Node.
C) Designing of smart Base Station.
D) Implementation of the WSN at textile industry.

2. A. Hardware of Wireless Sensor Node.

Architecture of the wireless sensor node is depicted in figure 1. Moreover the circuit schematic is presented in the figure 2. It is known that, the wireless sensor node is the realization of embedded system design, wherein both hardware as well as software should be co-designed.

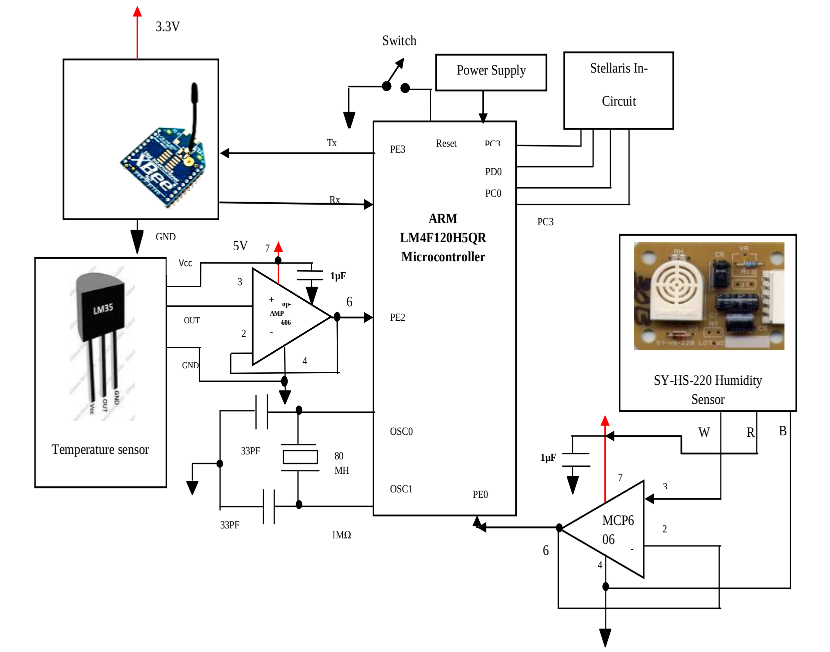


Figure.2 Schematics of the Wireless Sensor Node designed for monitoring of environmental temperature and Relative humidity of the Textile Industry.

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, Xbee series-2 module etc. The sensors, such as temperature sensor LM-35 and SY-HS-220 humidity sensor have been deployed. These sensors are highly reliable and produce D.C emf, which is directly proportional to the actual values of respective parameters. An electrical signal produced by the sensors are conditioned. The signal conditioning circuit is wired about CMOS operational amplifier MCP606. On chip ADC of the ARM microcontroller, LM4F120H5QR [24], is employed for data conversion. The RF module Xbee series-2 transceiver is facilitated with UART interface. Therefore, it is interfaced with microcontroller at UART port. The RF module is configured to support IEEE 802.15.4 standards. Analog as well as digital part of present embedded system is designed and the designing issues are discussed subsequently through following points.

2.A.1 The Sensors

The system under investigation realizes the design of wireless sensor node for monitoring of industrial parameters, the temperature and humidity of the environment in particular. For this purpose the deployment of sensors of promising feature is necessary. Therefore, as discussed earlier the sensor modules LM-35 and SY-HS-220 humidity sensor are deployed as sensors. The details regarding these sensors are discussed through following sub sections.

2.A.1. (a)Temperature Sensor (LM-35):

The temperature is the one of the most important parameter in industrial process. Precision measurement of temperature is essential for variety of industries such as agro industry, food industry, food storage houses, sugar-cane industries; automobile industry etc. The temperature of the process and environmental temperature are two different measurand. The present wireless sensor network is implemented for monitoring environmental temperature in the textile industry. 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 sensor node. The LM-35exhibits typical accuracies of +/-0.25^{o}C at room temperature and+/- 0.75^{o}C over a full -55^{0}C to +150^{o}C temperature range. The current consumption is less than 60µA [25]. 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. Considering these facts the signal conditioning circuit is designed.

2.A.1.(b) Humidity Sensor [SY-HS-220]

The humidity is the major parameter as it decides the quality of the cotton yarn. The humidity specifies an amount of water molecules present in the air of textile industrial environment. The humidity sensor(SY-HS-220) is used to measure the relative humidity. Figure.3 shows photograph of an SY-HS-220 humidity sensor.

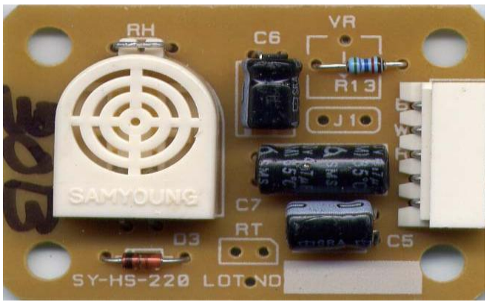


Figure.3 The Humidity Sensor SY-HS-220

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%. 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. 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.

2.A.2 Signal Conditioner:

As discussed earlier, both sensors are providing dc emf, which reveal linearity with respect to the variation in the parameters values. To realize the need of measuring instrumentation, the signal conditioning is in envitable. The signals under investigation are interfaced to the operational amplifiers, wired as signal conditioner. As depicted in figure 2, the signal conditioning circuit is wired about CMOS operational amplifier MCP606, which exhibits rail to rail characteristics for both input and output purpose. It suitably provides sinking and sourcing current at precise level. It exhibits ultra high input impedance and very low input offset voltages. 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 [27], which are essential features of the wireless sensor nodes. The signals are conditioned and then subjected to further process of digitization and calibration.

2.A.3 Computing Unit:

On extensive study of architecture of wireless sensor node, it is realized that the sensor node comprises a computing unit with promising features. Essentially, limited computing capability is the key feature of node. A computing unit of present node is designed about LM4F120H5QR microcontroller. The Data Acquisition System (DAS) is most important part of measurement instrumentation. On chip resources of the ARM microcontroller have been used to facilitate the designing of DAS for the dedicated system. Now days an embedded processor is coming with advanced features. Microcontrollers from ARM families are becoming more and more pervasive, because of their commendable features. The ARM microcontroller LM4F120H5QR is having promising on-chip features. It`s architecture is developed about ARM Cortex-M4 processing core. It proved its suitability for analog computation as well. 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. Each ADC module contains four programmable sequencers allowing the sampling of multiple analog input sources without controller intervention. 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. 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. 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). 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. Thus, the data converters are configured to ensure analog to digital conversion. The digitized data is used for further computation. A firmware is developed and ported into the target flash and used to synchronize above operations. Thus, the computing unit of present sensor node is designed and deployed to ensure autonomous operation of the wireless sensor nodes.

2.A.4 RF Module (Xbee Series - 2):

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. For present nodes the Xbee series-2 RF module are employed. The Xbee transceiver RF module from DIGI international Inc, is operated according to IEEE 802.15.4 standards, within the 2.4 GHz unlicensed ISM band. This chip enables industrial grade applications, at low voltage operation. The features of this RF module, Xbee transceiver, have been given in [28].

According to architecture of this RF module, it is a 20 pin RF module and it provides UART interface. The minimum pin required to interface with UART are VCC, GND, Rx and Tx. 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 Xbee series-2 for transmission. The Xbee series-2 RF module receives the parameter values from microcontroller. The Xbee series-2 uses IEEE 802.15.4 standard packet format for transmitting the data.

2. B. Firmware for Wireless Sensor Node:

The software employed in sensor node (END Device) developed by using Code Composer Studio (CCS) IDE in embedded ‘C’ environment. In this IDE typical software modules are developed for monitoring the industrial parameters. In the beginning, the RF Xbee module is initialized and allowed to search the network. It operates in polling mode. On availability of the network, immediately it joins the network. Meanwhile, the processing unit, ARM microcontroller, provides the digital data proportional to the parameter values. An empirical expression obtained from the process of calibration are deployed in the firmware. On continues execution of these expressions the computing unit produces the values of the parameters, under investigation, in real units. Serial communication module initializes the UART module and then transmits the data in specific format towards the coordinator node. Thus, the wireless sensor nodes are designed for realization of wireless sensor network.

2. C Base Station (BS):

According to structural design of the WSN, the base station is equally important. It comprises co-ordinator node and the desktop. It is essential for demonstration and storing of the data in specific format of the data.

The schematic of the base station is depicted in figure 4. As shown in figure 4, the base station comprises the co-ordinator node and computer for demonstration of data. 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.

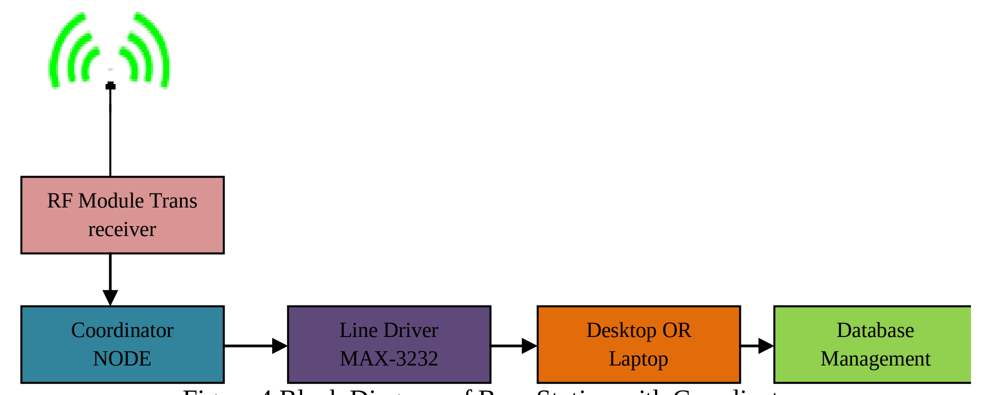


Figure.4 Block Diagram of Base Station with Coordinator

Moreover, embedded firmware is also designed and ported into the target device. As shown in figure 4, the co-ordinator is connected to computer system through serial interfaced. An UART is used to ensure interfacing of co-ordinator to the computers. The coordinator is interfaced with to computer system through the line driver MAX3232. For base station, Site Specific Data Monitoring (SSDM) Graphical 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.

The Graphical User Interface (GUI) is designed in Visual Basic (VB 6.0), environment to facilitate the base station (BS) of wireless sensor network (WSN). The wireless sensor network incorporates the Base Station (BS) to monitor the distributed data regarding industrial parameters. As per the structural design of the wireless sensor network (WSN), the nodes have been designed and routed by ensuring Zigbee technology. The node collects and disseminates the site specific data towards the base station. In fact, the present design is devoted for measurement of industrial parameters. Therefore, the parameters values should be demonstrated in user’s friendly format. The graphical demonstration of data is always suitable. 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).

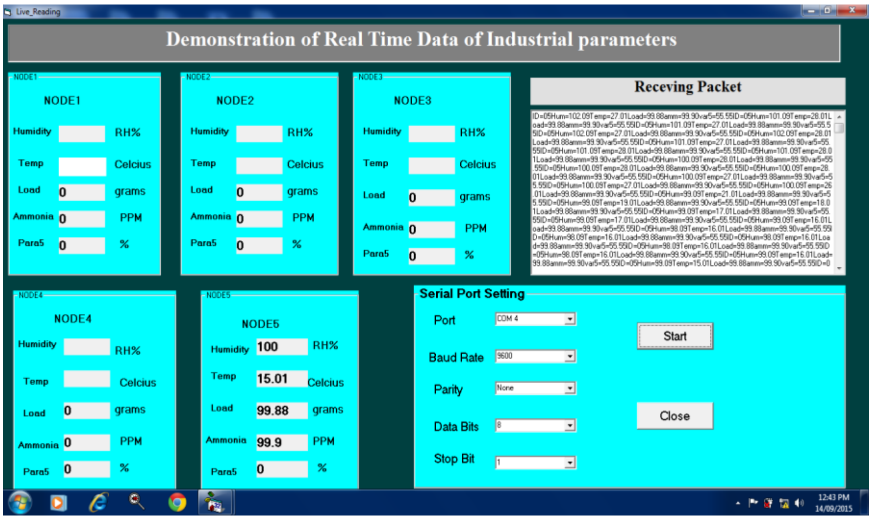


Figure.5 Snapshot of VB Based GUI for Live Monitoring of Parameters of textile industry.

The photograph of GUI shown on the desktop is presented in figure 5, designed and implemented. 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 and identifiers. The parameter values, temperature and relative humidity are extracted and displayed into respective windows. The windows are continuously updated with the recent data. Typically, for present WSN, 5 nodes are routed. Therefore, 5 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.

III. CALIBRATION OF THE SENSOR NODE:

As discussed earlier, the wireless sensor nodes have been designed by co-developing of both hardware and firmware. Moreover, present nodes have been designed to monitor the parameters of site specific relevance. The calibration of the device is the facet of the measurement instrumentation. Therefore, before implementation, the nodes are calibrated to the respective scientific unit. The nodes have been designed to monitor environmental temperature and relative humidity of the textile industry. Therefore, the nodes have been calibrated to the respective units and methods adopted for the calibration are discussed through subsequent points.

3.(a) Calibration of the Node to the Temperature in Degree Celsius:

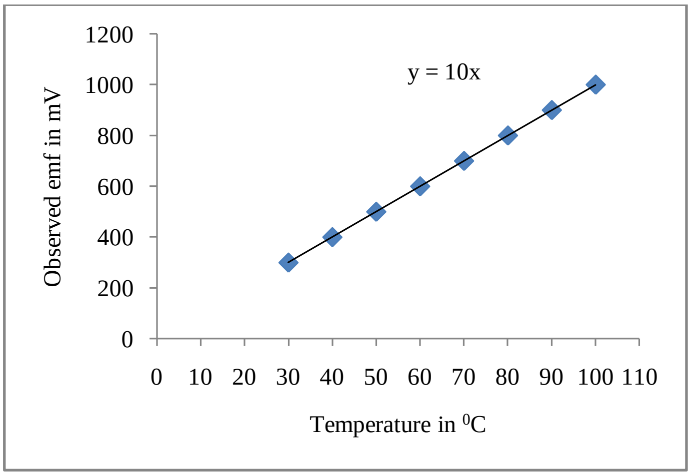


Figure.6 Graph of observed emfV_t (mV) against applied temperature t (^{0}C)

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 ($\alpha_{t)}$ is 10mV/^{0}C. 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 in ^{0}C, is shown in figure 6. The graph, the calibration curve depicts linear variation. On implementation of regression process, an empirical relation, equation 1, is obtained.

$V_t = 10\,t$ …(1)

On inspection of equation 1, it is found that, the emf shown by analog section of the node has temperature coefficient of $10mV/^0C$. This may be due to temperature coefficient of the sensor [25]. Therefore, the equation 2,

Temperature of an Environment (t) = $V_t / 10$ …(2)

is employed in the firmware, which executes to produce continuous values of temperature in degree centigrade. Thus, the sensor nodes have been calibrated to the temperature in degree Celsius. Further, the system is also standardized with standard thermometer. The values of temperature shown by the standard digital thermometer and that of shown by present system are tabulated and presented in the figure 7. The close match of the temperature values supports the reliability of hardware and software design.

3.(b) Calibration of the nodes to the Humidity in %RH:

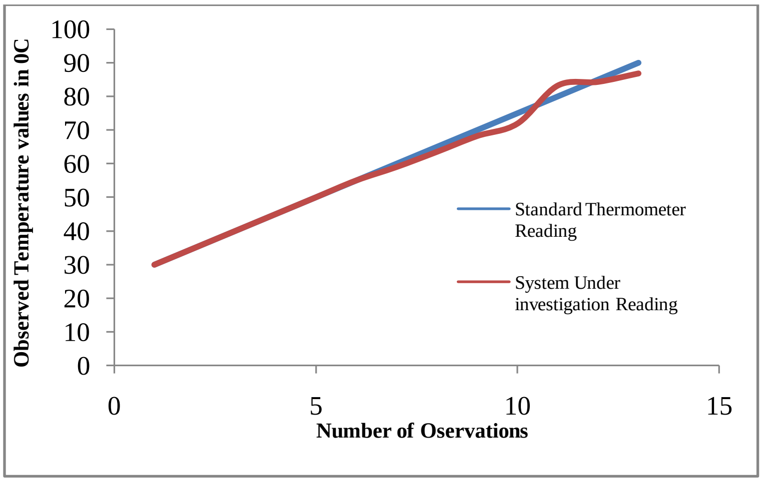


Figure 7 Temperatures Shown by the System under Investigation and Standard Thermometer.

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 8. The graph of observed emf (V_H) plotted against humidity (H) in %RH is shown in figure 9. The graph depicts linear variation. On implementation of regression process an empirical relation, equation 1, is obtained.

Figure.8 Experimental arrangement for calibration of the system under investigation.

$V_H = 0.024H + 0.697$ …(1)

The humidity dependant voltage (V_H) is recorded in volts. Therefore, the slope of the graph $\alpha_H = 0.024$, represents humidity coefficient of the system under investigation. Equation 1, reveals the 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, the emf should be 1980mV. 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 25^0C 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

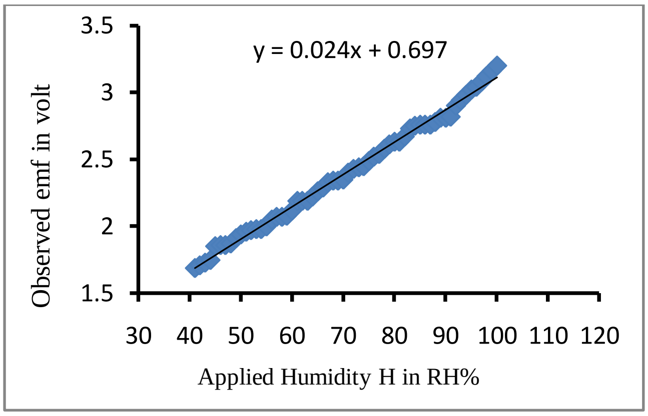


Figure.9 Graph of observed emf(V_H) against applied Humidity (H) in %RH

$$H = [(V_H - .0697) / 0.024] \qquad \ldots(2)$$

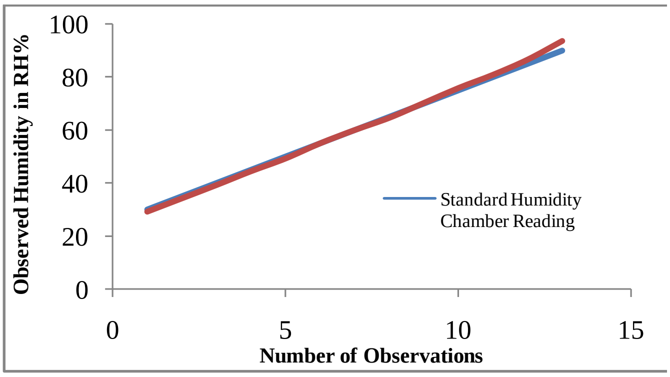


Figure 10 Humidity shown by the System under Investigation and Gayatri Scientific Chamber

This expression is employed in the firmware for the online processing of the data to produce output humidity in RH%. The system is also standardized with standard humidity meter. For standardization of the system, humidity from 30 to 90 RH% is applied by employing standard humidity chamber, Gayatri Scientific (India) make. Humidity values shown by the system are presented in figure 10. From figure 10, 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.

IV. IMPLEMENTATION OF THE WSN AT TEXTILE INDUSTRY

As discussed in earlier sections, the wireless sensor nodes have been designed and prototype of the typical node is presented in figure. Moreover, it is also calibrated to respective units. Now, these nods are ready for establishment of the network. The five nodes and co-ordinator are used and network is established in star topology, wherein all nodes are sending data towards co-ordinators. In the beginning, to realize the operation of WSN, the nodes were placed systematically, on the play ground and data send by each node is recorded at the base station. Moreover, on-site implementation of WSN for on-line monitoring of dedicated industrial parameters is one of the objectives.

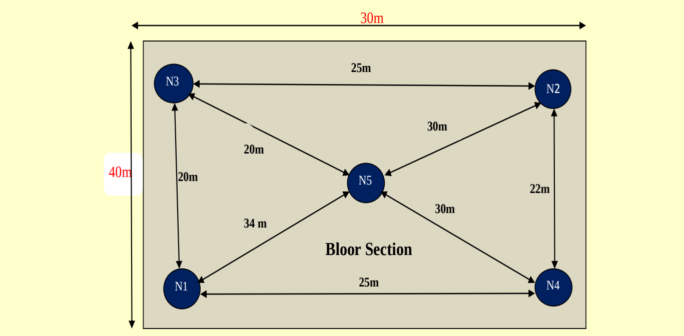


Figure 11: Schematic of arrangement of the Sensor Nodes in the Blower section of the textile industry

For on-site implementation, a textile industry of Fabtech Projects and Engineers Ltd (Textile Division), Ekhatpur, Sangola was selected. The Textile division of Fabtech industry has four sections such as Blower section, Preparatory section, Spinning section Ring Conner section etc. Out of these four sections, in this paper, WSN under investigation is deployed in the Blower section. The five sensor nodes of the WSN under investigation are deployed and results of investigation are presented in this article.

V. EXPERIMENTAL SET-UP

The WSN is established in the Blower section of the industry. The schematic arrangement of the sensor nodes is presented in figure 11. As shown in figure 11, the nodes are systematically deployed to cover maximum area of the Blower section. The distance between sensor nodes and based station is also considered. The distance between sensor nodes and based station is depicted in table 1. For present investigation, two environmental parameters such as environmental temperature (^{0}C) and relative Humidity (%RH) are emphasized.

Table 1: Distance of Nodes placed in the Blower section from Base station.

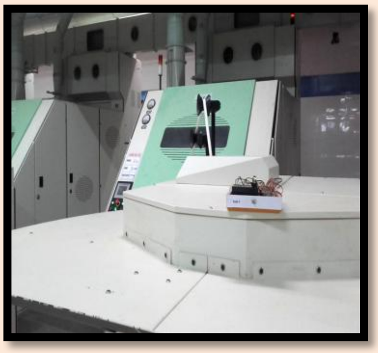
Sr. No.	Sensor Node	Distance from Base Station (m)
1	Node 1	30
2	Node 2	48
3	Node 3	51
4	Node 4	42
5	Node 5	36

The Base station established for present investigation is shown in figure 12. Location of the Base Station is kept same for entire experiment. Actual experimental arrangement of the sensor nodes in the Blower section, which ensures the Site Specific Data Management, is presented in the figure 13. The Sensor nodes collect the information regarding relative humidity and temperature of the region under investigation. After processing at node level, the data is packetized according to the MAC and disseminated toward Base station in star topology. The data given by the sensor nodes are demonstrated on the GUI of the base station and stored in the data base for further interpretation.

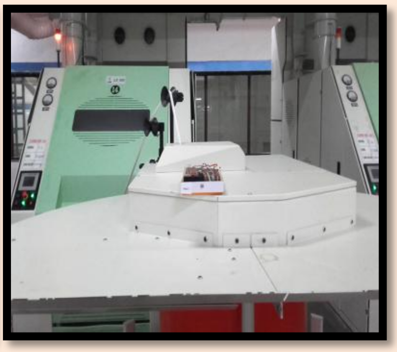
VI. RESULTS AND DISCUSSION

The WSN under investigation is deployed in the Blower section of the textile industry. Experimental arrangement is shown in figure 12 and 13. The Blower section realizes the cleaning of the cotton using air pressure. The each Sensor Node of the WSN are collecting information regarding environmental temperature and relative humidity of the region where it has been deployed. In fact, the textile division is also having digital thermometers and Humidity meters. These meters are installed at typical location only and not spread into the entire area of investigation. Therefore, these meters are showing parameter values at respective local point only and do not cover entire area of textile division. Moreover, these

Figure 12: Installation of the The Base Station of the WSN for Blower section of the textile industry



a)Wireless Sensor Node-1



b) Wireless Sensor Node-2

c) Wireless Sensor Node-3

d) Wireless Sensor Node-4

e) Wireless Sensor Node-5

Figure 13 (a-e): Experimental arrangement of the Sensor Node 1 – 5 within Bloor section of the Fabtech industry (Textile division), Pvt Ltd Sangola Dist- Solapur (India)

meters are not networked. Therefore, the system available in this section does not reveals the central monitoring and control as well. Also, the data logging facilities are not available in this system. Therefore, the WSN under investigation plays remarkable job of data collection and monitoring. Moreover, it is known that both temperature and humidity are the parameters of site specific variability. It also depicts the spatio temporal variation. Values of these parameters specified by the Fabtech industry to maintain the quality of cotton are 32^0C and 55 RH%, respectively for temperature and humidity. The Wireless Sensor Network (WSN) under investigation is implemented for monitoring of temperature and humidity of the indoor environment of the Blower section of the textile division. The instantaneous values of these parameters are recorded and stored into the database of the Base station and interpreted in this section. In fact, an experiment of deployment of WSN for monitoring of the parameter is carried for 10 days and for different periods of the day. However, the data regarding these parameters for typical duration is presented in this section. An accumulated data is not only demonstrated on the GUI but also stored in the real time.

6.a) Monitoring of Relative Humidity (RH%) of Blower section:

The values of relative humidity (RH%) sensed by various sensor nodes and collected at the Base Station are plotted against time in Minute. The graph of humidity against time is depicted in figure 14. On inspection of Figure 14, it is found that, an average relative humidity is about 55 RH% as expected. Values shown by the system under investigation and that of obtained from standard system installed by the industry are found close match. This supports the reliability of the WSN under investigation. From figure 14, it is also found that, the humidity within the area of investigation is not uniform. The values depict site specific variability. The values also show time dependence. The values of the humidity vary within 50 % RH to 60%RH. On the inspection of the figure 13, it is observed that, the relative humidity of the area

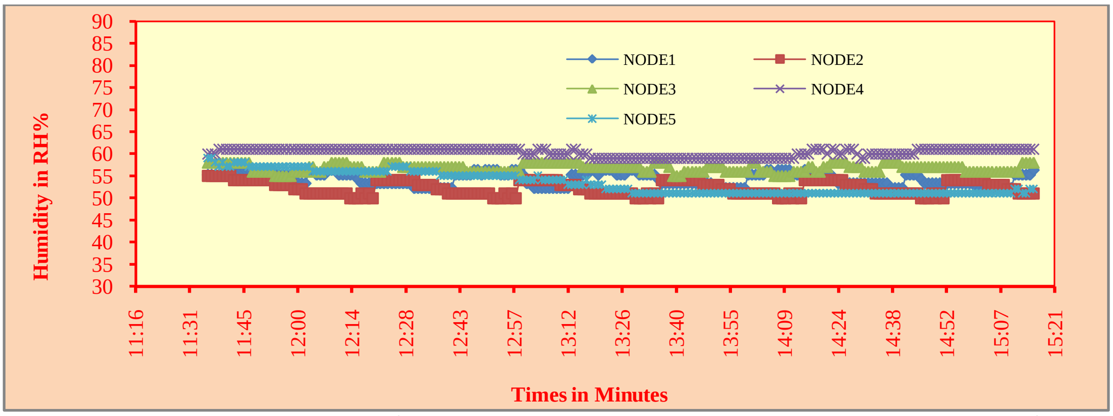


Figure 14: Instantaneous values of relative humidity in (RH%) measured in an environment of the Blower section of the textile division of the Fabtech industry Pvt Ltd Sangola Dist-Solapur (India).

of Sensor Node1 ranges 53%RH to 56%RH. The Sensor Node 2 shows the humidity value within the range from 51%RH to 55%RH. The sensor Node-3 and 4 show the humidity values is in range from 56%RH to 58%RH. However Sensor Node 5 and sensor node-5 shows the humidity values in range of 59%RH to 61%RH. The WSN under investigation precisely depicts the site specific variability in the indoor parameter values.

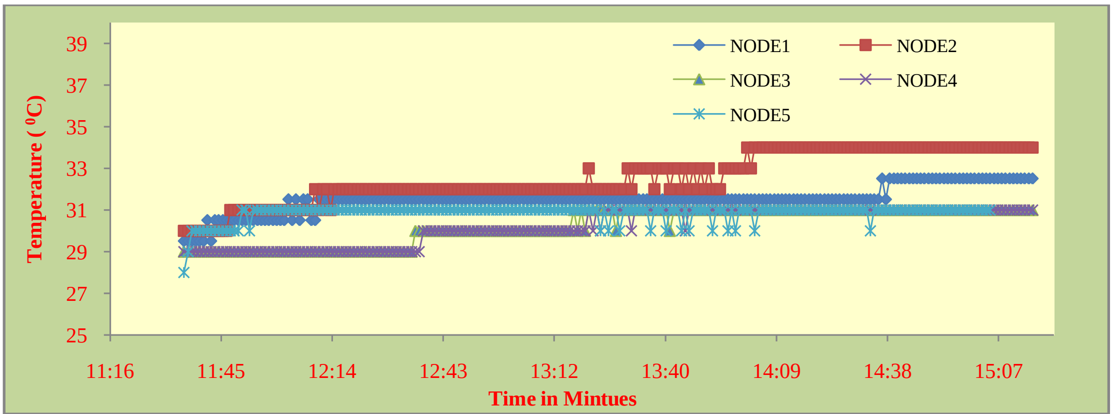


Figure 15: Instantaneous values of environmental temperature in (^{0}C) measured in an environment of the Blower section of the textile division of the Fabtech industry Pvt Ltd Sangola Dist-Solapur (India).

6.b) Monitoring of Environmental Temperature (^{0}C) of Blower section:

Instantaneous values of environmental temperature in ^{0}C are recorded against time in minutes. The data is also stored in the data base of the Base station and used for further presentation. The values of Environmental Temperature (^{0}C) sensed by various sensor nodes and collected at the Base Station are plotted against time in Minute. The graph of temperature against time is depicted in figure 15.

On the inspection of the figure 15, it is observed that, Sensor Node1 shows the temperature values in the range of 29^{0}C to 32^{0}C and that of Sensor Node 2 lies in between 30^{0}C to 34^{0}C. Moreover, the Sensor Nodes3 and 4 show the temperature in between 29^{0}C to 31^{0}C and Sensor Node-5 shows 30^{0}C to 31^{0}C. Average temperature shown by the WSN under investigation found close match with that of given by the standard digital thermometer of the textile division. Thus, from results of this investigation, it can be said that the wireless sensor network under investigation is most reliable, precise and suitable for real time monitoring of parameters of an environment of textile industry.

VII. CONCLUSION

Emphasizing industrial needs, the Wireless Sensor Network is developed to monitor typical industrial parameters such as temperature and relative humidity, wherein the sensors nodes are developed about ARM LM4F120H5QR microcontroller. Deploying sensor modules of promising features, the transducer interface section is developed. Ensuring the philosophy of the embedded technology, the nodes have been designed, wherein the zigbee devices have been used to realize the wireless networking in which the standards of IEEE 802.15.4 are followed. The nodes have been calibrated to real units and standardized with sophisticated instruments. To realize on-site implementation the WSN under investigation is deployed in the environment of the textile industry to collect the information of the said parameters. For realization of an site deployment present WSN is deployed at blower section of the textile industry. The data regarding environmental temperature and relative humidity of the textile industry is monitored on the dedicatedly designed GUI at base station. The results obtained are in close math with the standard results, which revealed the reliability and preciseness of the WSN under investigation. It can be concluded that, the WSN under investigation is most suitable for monitoring of indoor environment of textile industry.

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