www.s2is.org
International Journal on Smart Sensing and Intelligent Systems
ISSN 1178-5608

DEVELOPMENT OF SMART DETACHABLE WIRELESS SENSING SYSTEM FOR ENVIRONMENTAL MONITORING

D. Bhattacharjee and R.Bera
Electronics & Communication department
SMIT, SMU, INDIA
Emails: dipanjanbhattacharjee@yahoo.co.in
rbera50@gmail.com

Submitted: May 5, 2014 *Accepted: July 22, 2014* *Published: Sep. 1, 2014*

Abstract- We present the work on development of Smart Detachable Wireless Sensing System for environment monitoring (SDWSS) complying with the IEEE 1451 standard. Barometric and alcohol two different detachable smart sensor have been developed by incorporating generic transducer, customized peripheral interface controller (PIC) 18LF2550 microcontroller and with other peripherals. Detachable smart transducer interface module (DSTIM) implemented using centralized PIC 18F4550 microcontroller based embedded platform, and wireless communication is achieved by 2.4 GHZ XBEE, and CC2500 based wireless module. Various intelligent power management protocols have been implemented on the detachable sensors. This is a flexible cost effective smart system ideal for distributed environment monitoring application.

Index terms: Smart sensor, IEEE 1451, SDWSS, peripheral interface controller, Detachable smart transducer interface module (DSTIM), distributed monitoring. XBEE.

I. INTRODUCTION

The energy any efficiency become a vital concern for sustained growth and development. Today it is proved that for high pollution and climate change the human activity is highly responsible. The need for inexpensive and flexible smart environmentally hazardous gases detection and quantification system becomes more important due to elevated atmospheric pollution. Environmentally hazardous gases include green house gases such as N_2O, CH_4 and CO_2, toxic gases such as H_2S, CO and NH_3. NO_2, NO and SO_2, which are both toxic and green house gases. Green house gases trap heat and make the planet warmer, from last 150 year human activity almost responsible for increase in green house gases in the atmosphere. According to the Intergovernmental Panel on Climate Change (IPCC) report, global greenhouse gas emission from 1970 to 2004, due to human activities rose by 70% [1]. According to EDGAR (database created by European Commission and Netherlands Environmental Assessment Agency) released 2012 estimates of annual CO_2 emissions (in thousands of CO_2 tones) per year in different country world wide. China emits 9860000 tons of CO_2, United States emits 5190000 and India 1970000 tons of carbon dioxide per year [2]. Toxicity and threshold limit value (TLV) is defined as the maximum concentration of a chemical allowable for repeated exposure without producing adverse health effects [3]. To reduce the environmentally hazardous gas emission and to provide a better environment, it becomes very important to monitor the environment uninterruptedly and most important correctly by the help of smart detection system [4]. Many studies have been done to find out how to reduce the carbon emission, and study says that it is possible to reduce the carbon emission by 60% or more by continuous monitoring and using commercially available technologies[5]. Hence, there are huge demand for intelligent portable distributed environmental monitoring and control system, which can detect and quantify the source of pollution rapidly and propagate the information to desired remote monitor station [6-8]. Many works have been done on design and development of environmental monitoring, system where priority is given to sensor array based development, previous studies did not focus on the issues like flexibility and distributed monitoring in cost effective way [9-12]. Here author presents the development of a flexible detachable wireless smart sensing system for distributed environmental monitoring.

II. LITERATURE REVIEW

An Environmental Air Pollution Monitoring System (EAPMS) for monitoring the concentrations of major air pollutant gases has been developed, complying with the IEEE 1451.2 Standard [13]. This system measures concentrations of gases such as CO, NO_2, SO_2, and O_3 using semiconductor sensors. The smart transducer interface module (STIM) was implemented using the analog devices' ADuC812 micro converter. Network Capable Application Processor (NCAP) was developed using a personal computer and connected to the STIM via the transducer independent interface. [14] Proposed the design of 6LoWPAN physical layer transducer electronic datasheet using data type redefinition with the header compression. Similar kind of work implemented, where STIM is implemented using PIC 18F4550 microcontroller [17]. The process of optimum selection of sensor among different alternative sensors based on analytic hierarchy process (AHP) presented [15]. The development of low cost wireless chemical sensor network, in which light sensor was used as the chemical sensing platform is discussed [16]. The one way wireless communication is achieved by 868 MHz Frequency Shift keying (FSK) transmitter. Some years ago Crossbow [17] began to market the MEP-SYS kit for monitoring environmental parameters. This product, comprising two types of nodes, can be used to monitor ambient temperature, relative humidity, radiation and barometric pressure. Moreover, thanks to their protective casing these motes can be used for both open-air and greenhouse crops. Some other manufacturers are proposing similar solutions to Crossbow's [18, 19].

49C O3 ANALYZER — Portable gas detector — 8800 CO/Combustable Gas detector

Figure 1: various portable environmental monitoring instruments.

In other hand, there are others platforms developed in the framework of research projects [20, 21] that uses general purpose motes (MICAzTM, TelosBTM, etc) enclosed inside watertight boxes. Some of the readily available environmental monitoring system is shown in fig. 1

III. DETACHABLE SENSOR CONCEPT, DESIGN CONSIDERATION AND SYSTEM ARCHITECTURE

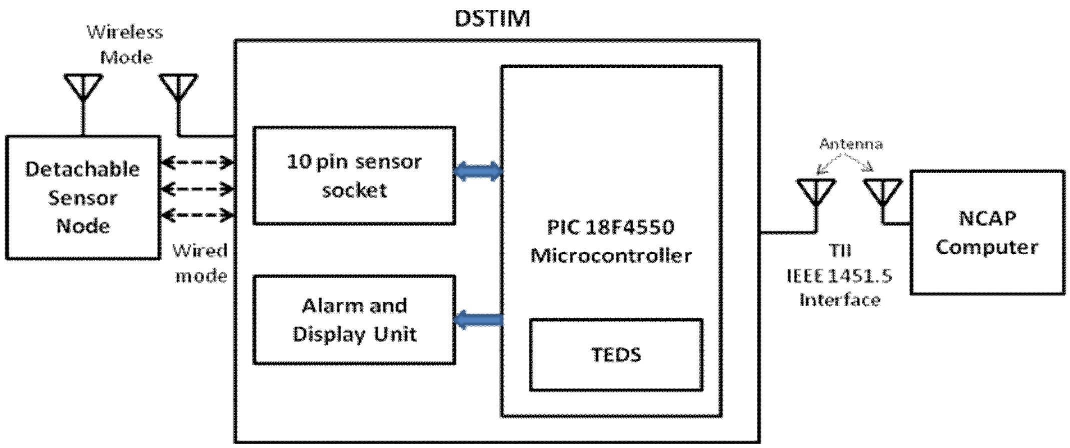

Figure 2: Architecture of Smart detachable wireless sensing system.

A typical sensor array consists of different types of sensor which are connected in a common platform. High sensing efficiency and initial alarming can be achieved, if sensors are placed near to the source, so if we need to sense different parameter distributed way in different geographical location, a single sensor array can not perform the task. Implementation of multiple sensor arrays can be the solution, but it will enhance the development cost and will not full meet system portability and power consumption criteria. So to achieve distributed in situ measurement a flexible compact and detachable distributed monitoring system is essential. The detachable smart sensor is a new concept; it consists of all the required components of a wireless sensor node in minor level. It has low power wireless module, a small battery and processing unit. The plug and play features enable detachable sensor to behave like an ordinary sensor of a sensor array, when it is attached to its base (DSTIM). In this mode all peripherals will be deactivated. When distributed sensing required the sensor can be detached from the base. On detachment internal

Components	Operating voltage range	Power consumption
PIC 18LF2550	2-5.5.V	5.8µA idle mode 0.1µA sleep mode
PIC 18F4550	4.2-5.5V	5.8µA idle mode 0.1µA sleep mode
BMP 085	1.8-3.6V	5µA at 1 sample/sec
MQ-3	Circuit= 5V Heater= 5V	750mw
XBee -S1	2.8-3.4V	Rx=50mA power –down<10µA
CC 2500	1.8V – 3.6V	Rx=13.3mA Power-down= 400nA

Table1: Major components of DSTIM

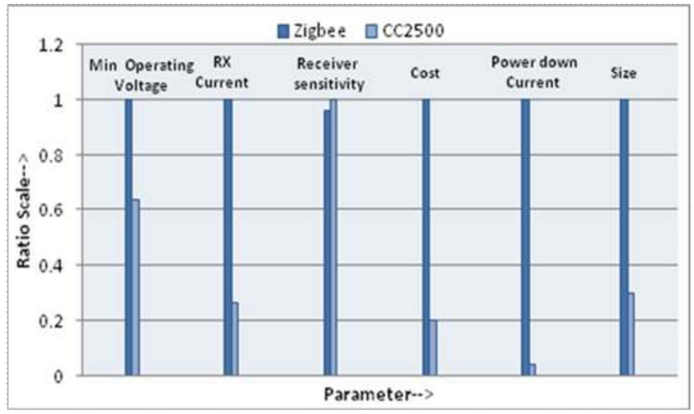

Figure.3: XBEE and CC 2500 comparison.

system will activated automatically and sensor will communicate with DSTIM in wireless mode with the help of CC 2500 2.4 GHz transceiver. The basic architecture of smart detachable wireless sensing system is shown in Figure.2. The key parameters for hardware selection are cost, power consumption and size. Table. 1 describes the major components used in DSTIM system along with operating voltage range and power consumption data. Figure 3 represents the parametric comparison between XBEE and CC2500 transceiver. From the graph it is clear that CC2500 is optimum selection for detachable sensor which offers minimum operating voltage low power consumption, cost effective with minimum dimension compare to XBee module. XBee is used for DSTIM to NCAP communication using IEEE 1451.5 standard. The PIC 18LF2550 is selected for detachable node due to low I/O pin requirement. PIC 18LF series is a high performance, enhanced flash microcontroller with nano Watt technology. It can be operated at a min voltage of 2 V with 4 MHz clock, which is optimum for low voltage battery operated detachable sensor. DSTIM requires more I/O pins for interfacing compare to detachable node, so 40 pin PIC 18F4550 microcontroller selected for DSTIM. .

IV. CONSTRUCTION OF WIRELESS DETACHABLE SENSORS

Three different detachable sensors have been developed along with Smart Transducer Interface module (STIM), the detachable barometric pressure sensor designed based on BMP 085 MEMS sensor which is interfaced with microcontroller by I2c serial bus. The module Powered by 3V, CR2 battery and workable between 2V to 3V. CC 2500 transceiver is controlled

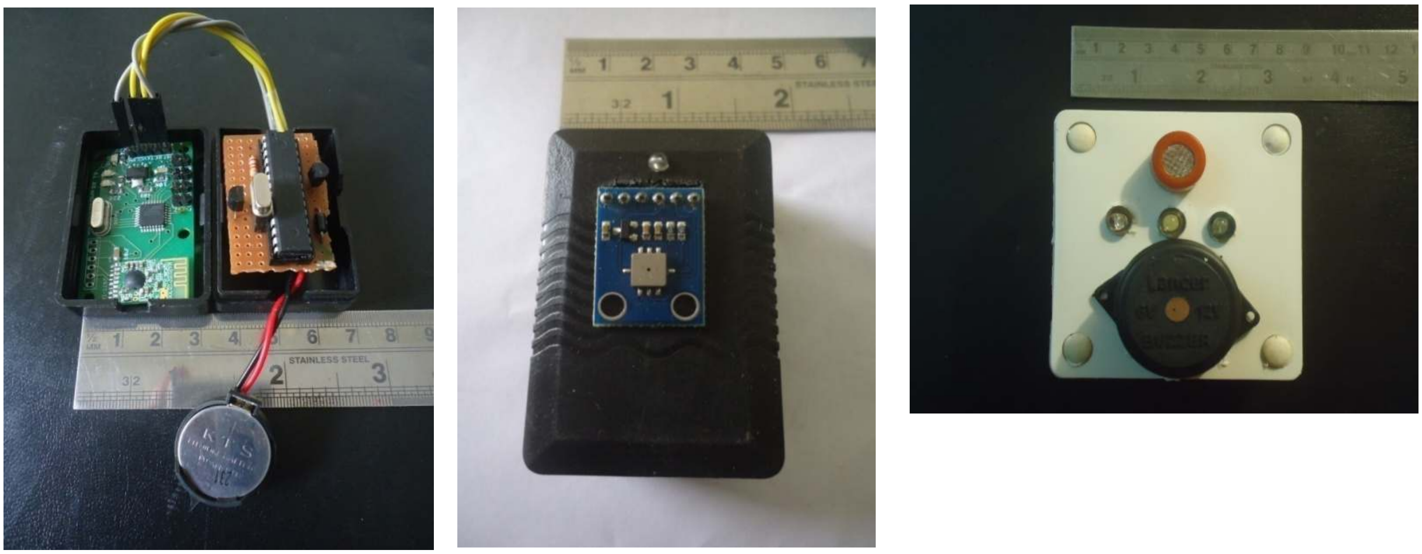

Figure 4: Hardware proto types of wireless detachable Barometric sensor, its internal components and detachable alcohol gas sensor

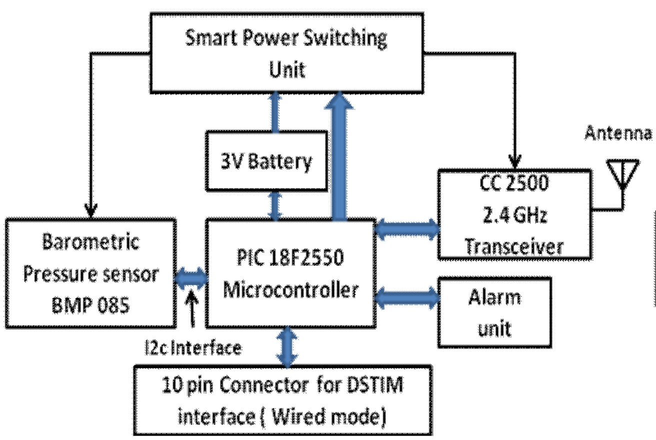

Figure 5: Detachable barometric sensor architecture

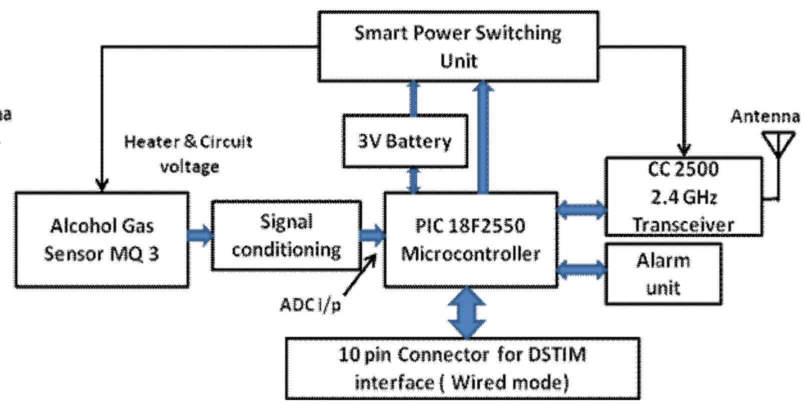

Figure 6: Detachable Gas sensor architecture

via serial peripheral interface (SPI). The Detachable sensor can be interfaced to DSTIM wirelessly or by 10 pin physical connector. Smart power switching unit is the most important part for both the detachable sensor because it supply power to various unit of the sensor system depending on the power management modes. Microcontroller issues various control signals to the smart power switching unit. Mq-3 is tin oxide (SnO2) based semiconductor gas sensor having high sensitivity in alcohol. Approximately 750mW power supplied from the power switching unit.

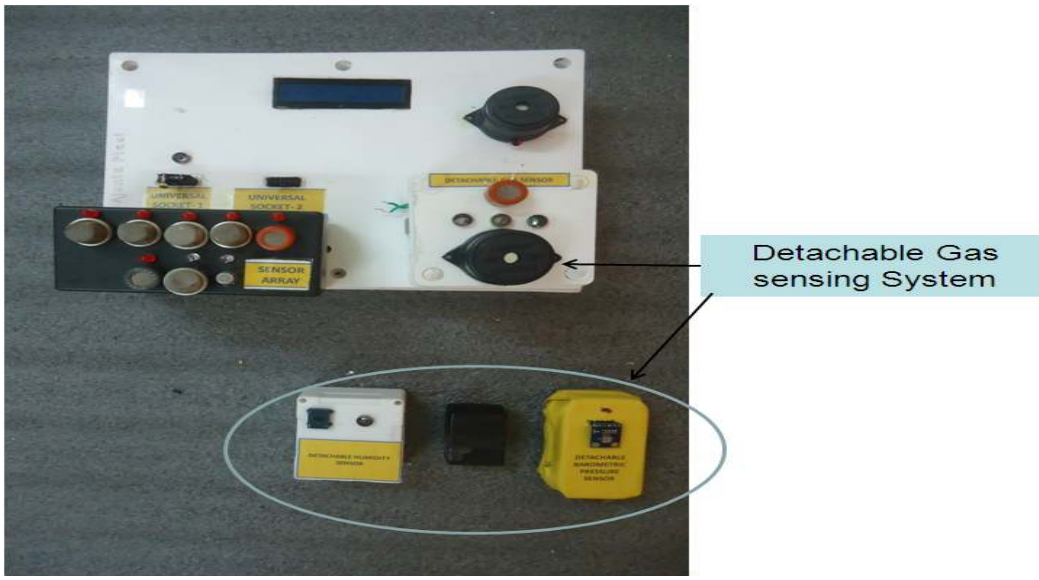

Figure 7: Full system setup Detachable Gas sensor mounted on the base and two different detachable sensors connected via wireless with the STIM.

After initial signal conditioning sensor output is fed to the internal analog to digital converter (ADC) of the microcontroller. MQ-3 need regulated 5V power supply, unregulated supply can hamper the sensors sensitivity and selectivity profile. The system is powered by a 6V 1000 mAh rechargeable lithium ion battery and can be interfaced with DSTIM by wireless or 10pin physical connector. The STIM is interfaced with the NCAP via 2.4 GHz XBee communication module.

V. FUCTIONALITY OF DETACHABLE SENSOR NODE

Every detachable smart sensor have two possible states, either it is attached to the DSTIM by the 10 pin connector or is detached from the DSTIM socket. For initial powering detachable sensor should be connected in the DSTIM. While attached detachable sensor draws power from the base. When the sensor is detached from the base, it power up the internal wireless transceiver (CC2500) immediately and checks for sensor locking information. If the sensor is locked from the remote monitor station, it immediately broadcast a alarm signal to remote monitor. And If the sensor is not locked, system reads the battery voltage level and select the appropriate power management mode if it is not set from remote monitor, for efficient use of battery power. There are four different power management modes which can be select automatically by the system or can be set supervisory from the remote monitor. All the power management mode have their default threshold point for switching, remote monitor can also set the threshold level of these modes. The threshold point for BMP 085 based barometric pressure sensor are 2.5V, 2.3V, 2.1V and 2V, which has been shown in Figure. 8. The last threshold point has been set to 2V because it is the minimum operating voltage of the PIC 18F2550 microcontroller, though minimum operating voltage for CC 2500 wireless module and BMP 085 sensor is 1.8V.

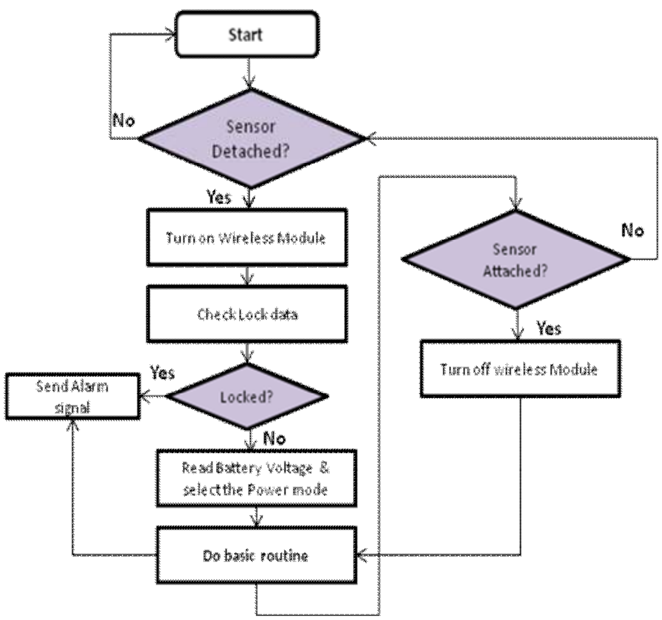

Figure 8: Flow diagram for attachment and detachment of sensor

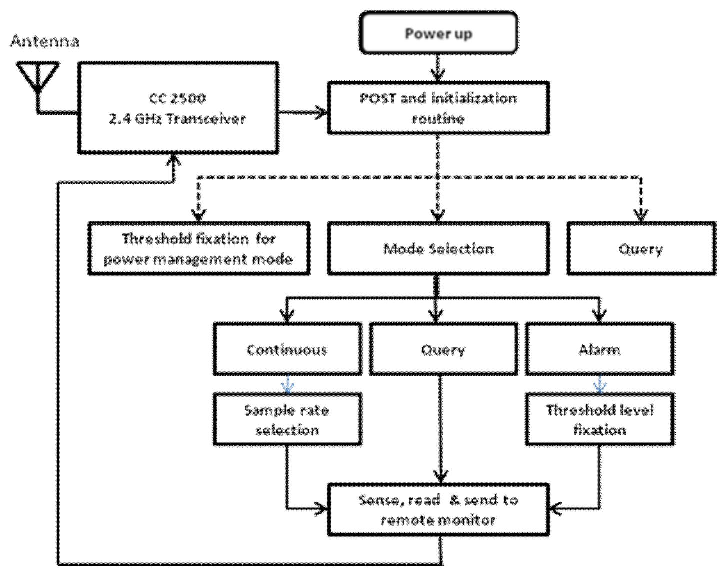

Figure 9: Flow diagram of sensor in stationary mode

Figure. 8. Shows the internal operation performed in the detachable sensor, whenever state of detachable sensor changes. Figure.9. shows the flow diagram of internal operation performed in the detachable sensor in stationary mode. In stationary mode detachable sensor can be configured from remote monitor. Configuration parameters are: sample rate variation, threshold fixation, data mode selection etc.

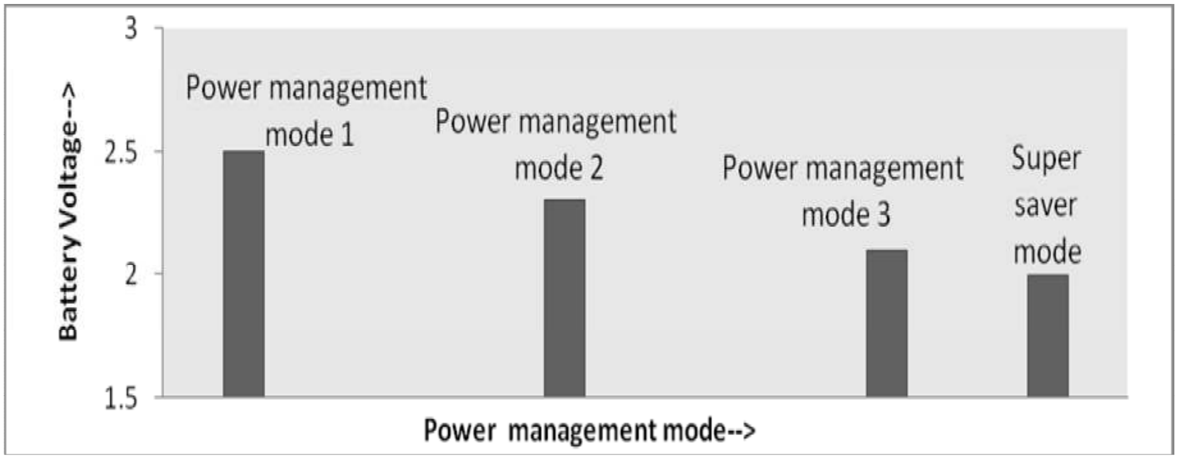

Figure.10: Various power management mode and threshold points.

VI. HARDWARE VALIDATION AND EXPERIMENTAL RESULTS

The initial experiments were conducted to obtain and understand characteristics and response of the sensors. The detachable alcohol sensor node has been tested in real time environment and the data received wirelessly in the remote monitor, continuous mode was selected for this experiment. The sensor response is shown in figure.12. The response have three different phases, the first phase is the initial response which is approximately 120sec, initial response may vary depending upon different sensor model and environmental condition like temperature and humidity. Initially the sensor is attached to the base and after few times it is detached to check time required to switch wireless mode. The missing data in the graph represents the switching period which is approximately 2 sec. The sharp increase in o/p voltage represents certain increase in alcohol concentration. The voltage line on the graph represents the voltage regulation efficiency. The detachable sensor can be operated in three different modes namely continuous

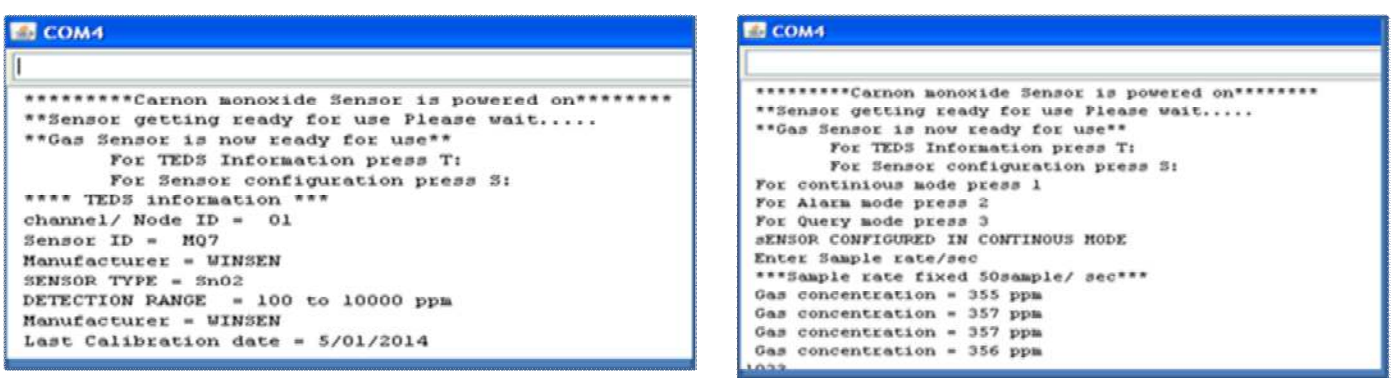

Figure 11: Interaction between NCAP and detachable sensor (serial window)

mode, query and alarm mode, in continuous mode user wirelessly can set the data sampling rate which may vary from 1sample/sec to 100 sample/sec. The TEDS information of the detachable sensor can be obtained by pressing 'T' from remote monitor, sensor TEDS information and data received in continuous mode at 50 sample/sec are shown in Figure 11. The query mode is designed to save the power due to unnecessary wireless transmission, in this mode detachable sensor will send the data if query initiated from the remote monitor 'Q' is used to active the query mode. To get intimation whenever the gas concentration exceeds some threshold level alarm mode is used, in this mode user can set the alarm threshold level for the sensor from remote station, the detachable sensor will activate alarm signal whenever the gas concentration exceeds the threshold level.

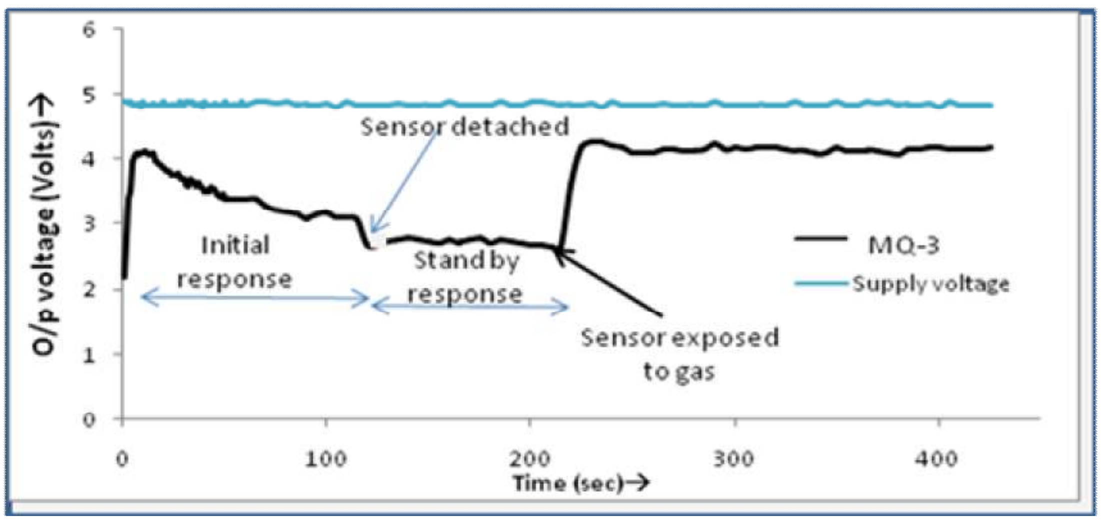

Figure 12: Three stage response of detachable gas sensor

Experiments have been performed on BMP 085 based smart wireless detachable barometric pressure sensor node to validate the hardware development and sensor response. The sensor can be operated in three modes namely query, continuous and lock mode, the first two mode is identical like gas sensor. The BMP 085 module provides three different data they are temperature, pressure and altitude. Figure 13, shows TEDS information and different operating modes along with some sample data obtained at the serial window of remote monitor. Data sample rate is kept at 5 samples per second, and the detachable sensor moved in different heights 2feet, 4 feet and finally to the 8 feet from its reference, and then taken back to the heights of 2 feet. The barometric pressure data obtained from the sensor is presented in Figure.14. We found high level of noise interference in the data and it is very difficult to observe the barometric pressure variation caused by the shifting of sensor position. To filter out the noise we have used moving average method and found maximum data retrieve efficiency by implementing eight points moving average filtering method presented in figure.15. In supervisory mode NCAP interact with detachable sensor node for transducer electronic data sheet (TEDS) information,

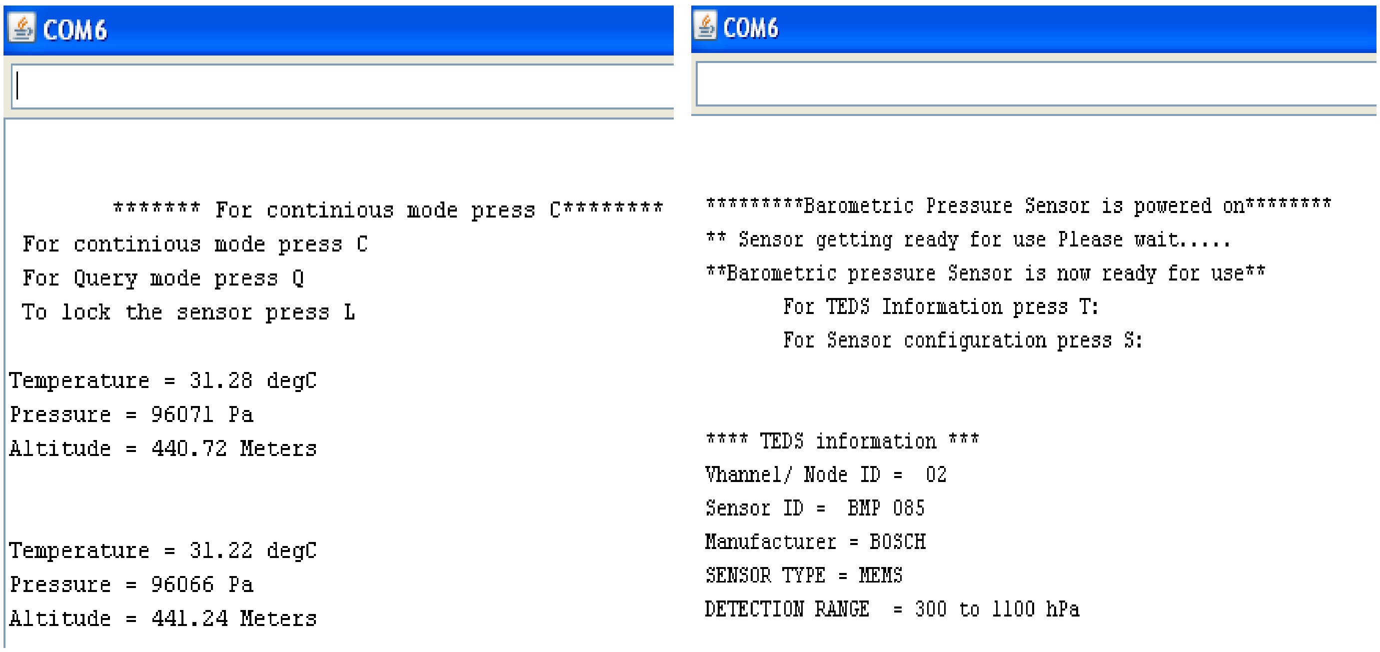

Figure 13: TEDS information and various operating mode of detachable barometric pressure sensor

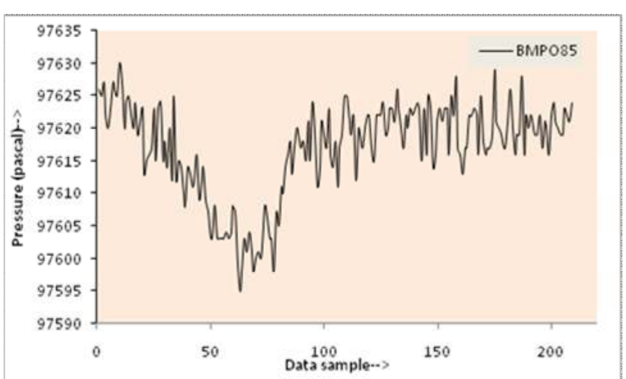

Figure 14: Barometric pressure data

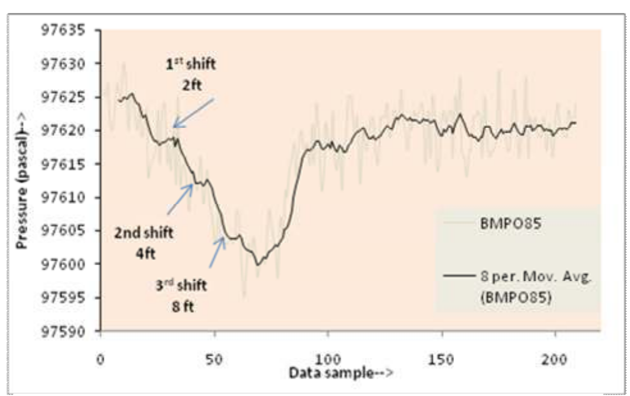

Figure 15: Barometric pressure data after noise filtering

User can interact configure the sensor modes and for other need via DSTIM. The interaction is achieved by writing various commands in serial window of the computer terminal. An important

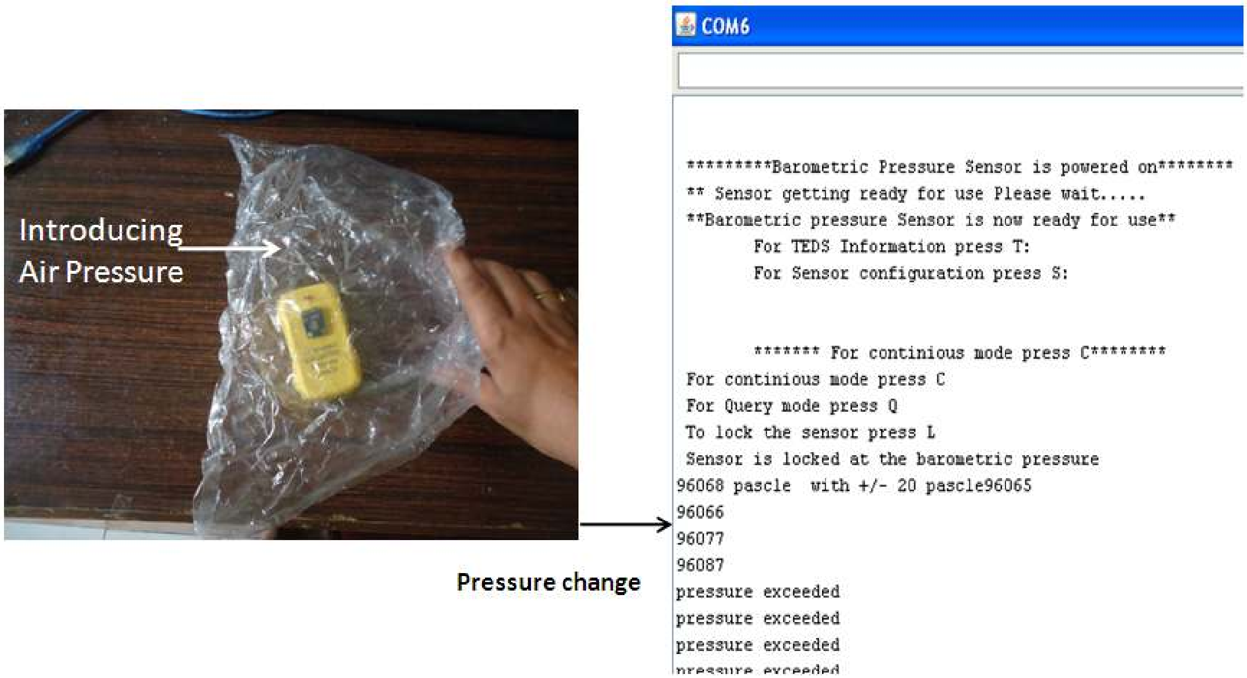

Figure 16: Barometric pressure lock mechanism and alarm propagation

Feature of detachable barometric pressure sensor is that the pressure can be locked from remote station; this mode can be activated by writing ‘L’ in serial window. If the barometric sensor locked and environmental barometric pressure exceed above threshold level automatically alarm signal will be generated and same information is displayed on the remote monitor terminal, the detachable sensor will come to its normal mode whenever the pressure come down to normal value. Figure 16 shows pressure is being increased on the detachable barometric pressure module (left side) and pressure locking procedure and displayed alarm information on the serial window of serial terminal (right side).

VII. CONCLUSION

Smart detachable wireless sensing system has been developed successfully and validated in hardware level. The various operating modes of the sensor make the sensors more versatile. Detachable sensor functionality is verified and got expected results. In future work, we plan to conduct further analysis related to applying MEMS gas sensors for higher power and sensing efficiency. We will investigate the possibility of embedding reconfigurable hardware in the system.

VIII. REFERANCES

[1] R. K. Pachauri and A. Reisinger, “Climate change 2007–impacts, adaptation and vulnerability,” Contribution of Working Group II to the Fourth Assessment Report of the IPCC, Geneva, Switzerland, 2007.

[2] Jos G.J. Olivier (PBL),Greet Janssens-Maenhout (IES-JRC), Marilena Muntean (IES-JRC), Jeroen A.H.W. Peters (PBL), “Trends in global CO2 emissions” 2013 Report © PBL Netherlands Environmental Assessment Agency The Hague, 2013 ISBN: 978-94-91506-51-2PBL publication number: 1148.

[3] The American Heritage® Medical Dictionary Copyright (2007), 2004 by Houghton Mifflin Company. Published by Houghton Mifflin Company.

[4] J. F. Nicol and M. A. Humphreys, “Adaptive thermal comfort and sustainable thermal standards for buildings,” Energy and Buildings, vol. 34, no. 6, pp. 563–572, 2002

[5] G. S. Brager and R. J. Dear, “Thermal adaptation in the built environ-ment: A literature Review”, Energy and Buildings, vol. 27, no. 1, pp.83–96, 1998

[6] D. A. Patterson, Technical perspective: The data center is the computer, Communications of the ACM, 51(1):105, 2008, pp. 105_105. N. Kularatna and B. H. Sudantha, “An environmental air pollution monitoring system based on the IEEE 1451 standard for low cost requirements”, IEEE Sensors Journal, vol. 8, no. 4, pp. 415–422, Apr. 2008.

[7] H. M. G. Ramos, J. M. D. Pereria, V. Viegas, O. Postolache, and P.M. B. S. Girao, “A virtual instrument to test smart transducer interfacemodules (STIMs),”IEEE Trans. Instrum. Meas., vol. 53, no. 4, pp 1232–1239, 2004.

[8]D. D. Lee and D. S. Lee, “Environment gas sensors, ”IEEE Sensors Journal, vol. 1, no. 3, pp. 214–215, Oct. 2001.

[9] Jaun A.Lopez, Fulgencio Soto, Pedro Sanchez, Andres Iborra, Juan Suardiaz and Jaun A. Vera, “Development of a sensor Node for Precision Hortculture”, Sensor 2009,9,pp. 3240-3255.

[10] Nihal Kularatna, Senior Member, IEEE, and B. H. Sudantha, Member, IEEE , “An Environmental Air Pollution Monitoring System Based on the IEEE 1451 Standard for Low Cost Requirements”, IEEE SENSORS JOURNAL, VOL. 8, NO.4, pp.415-422, APRIL 2008.

[11] Sukwon Choi , Nakyoung Kim , Hojung Cha and Rhan Ha. “Micro Sensor Node for Air Pollutant Monitoring: Hardware and Software Issues”, Sensors 2009, 9, 7pp. 970-7987;

[12] Jer Hayes, Stephen Beirne, King-Tong Lau, Dermot Diamond, “Evaluation of a low cost Wireless Chemical Sensor Network for Environmental Monitoring” IEEE SENSORS 2008 Conference, pp. 530-533.

[13] Sean Dieter Tebje Kelly, Nagender Kumar Suryadevara, and S. C. Mukhopadhyay, "Towards the Implementation of IoT for Environmental Condition Monitoring in Homes" IEEE SENSORS JOURNAL, VOL. 13, NO. 10, OCTOBER 2013, pp. 3846-3853.

[14] N.K. Suryadevara and S.C. Mukhopadhyay, “Wireless Sensor Network Based Home Monitoring System for Wellness Determination of Elderly”, IEEE Sensors Journal, Vol. 12, No. 6, June 2012, pp. 1965-1972.

[15] Mohd. Amri Yunus, S. C. Mukhopadhyay and S. Ibrahim “Planar Electromagnetic Sensors Based Estimation of Nitrates Contamination in Water Sources Using Independent Component Analysis”, IEEE Sensors Journal, Vol. 12, No. 6, June 2012, pp. 2024-2033.

[16] Mohd. Amri Yunus and S. C. Mukhopadhyay, “Development of Planar Electromagnetic Sensors for Measurement and Monitoring of Environmental Parameters”, Meas. Sci. Technol. 22 (2011) 025107 (9pp), doi:10.1088/0957-0233/22/2/025107, January 2011.

[17]Crossbow Technology Company: San Jose, CA, USA; Available online: http://www.xbow.com/.

[18] Ranch Systems, LLC: Novato, CA, USA; Available online: http://www.ranchsystems.com.

[19]MorpH2O Water Management, LLC: Ogden, Utah, USA; Available online: http://www.morph2o.com.

[20] Rerkrai, K.; Jardak, C.; Kovacevic, A.; Riihijärvi, J.; Mähönen, P. Demo abstract: Survivable and scalable WSN solution for environmental monitoring in harsh conditions. In Proceedings of 6th European Conference on Wireless Sensor Networks, Cork, Ireland, UK, February 11-13, 2009.

[21] A. M. El-Sayed, F. M. Ismail, M. H. Khder, M. E. M. Hassouna, S. M. Yakout, Effect of CeO2 Doping on the Structure, Electrical Conductivity and Ethanol Gas Sensing Properties of Nanocrystalline ZnO Sensors, International Journal on Smart Sensing and Intelligent System, vol.5, NO.3, pp.606–623,2012.

[22] Dilip Kumar Ghara, Debdulal Saha, Kamalendu Sengupta, 'Implementation of linear trace moisture sensor by nano porous thin film moisture sensor and NLAmp', International journal on smart sensing and intelligent systems, Vol. 1 No. 4; pp.955-969, December 2008,.

[23] A. Che Soh, K.K.Chow, U. K. Mohammad Yusuf, A.J.Ishak , M. K. Hassan, S.Khamis, 'DEVELOPMENT OF NEURAL NETWORK-BASED ELECTRONIC NOSE FOR HERBS RECOGNITION', International journal on smart sensing and intelligent systems, VOL. 7, NO. 2, pp.584–609 June 2014.

[24] S. D. Shinde, G. E. Patil, D. D. Kajale, V. G. Wagh, V. B. Gaikwad and G. H. Jain, "Effect of annealing on gas sensing performance of nanostructured ZnO thick film resistors", International journal on smart sensing and intelligent systems, Vol. 5, no. 1, pp.277–294, 2012.

[25] Zhao Jindong, Fan Baode, Lu Yunhong, Mu Chunxiao,' N ADAPTIVE CHANNEL HOPPING ALGORITHM FOR WIRELESS SENSOR NETWORK WITH MESH STRUCTURE', International journal on smart sensing and intelligent systems, Vol. 3, no. 1, pp.377–395, 2011.