DESIGN AND DEVELOPMENT OF A SENSOR MODEL FOR COALMINES

Srinivasa A.H[1], G.Varaprasad[2†]

[1]Department of Computer Science and Engineering
Dr. Ambedkar Institute of Technology,
Bangalore 560 079.

[2]Department of Computer Science and Engineering
B.M.S. College of Engineering,
Bangalore-5600 19,
India.
Email: varaprasad555555@yahoo.co.in

Abstract: Wireless sensor network has a large number of sensors, which is used to collect the data from the environments. The sensor devices have a limited energy, memory, transmission range, and computation power. In this paper, we present a model called design and development of a sensor model for coalmines. The proposed model automatically detects the harmful gases such as Methane and Carbon Dioxide using PLS41 and KGJ sensors. It sends the sensing data to the control room through support node over the network. The control room takes necessary steps to prevent the accidents by considering threshold values of gasses. The proposed model is an efficient method to reduce the control message packets over the network.

Keywords: Wireless network, sensors, control room, alarm.

I. INTRODUCTION

Raw material like coal is used to make many products in the world. Discovering coal in different parts of India is responsible for many communities that have sprouted inland and brought many immigrants from the world to India[1]. The coalmines are very deep and the detection of harmful gases such as Methane and Carbon Dioxide is major task. It will reduce the loss of products and maximizes the coalminers safety[2]. Insufficient-light, presence of smoke and external problems can be occurred at the place where the coalminer works.

Methane gas is an odorless, tasteless, colorless and light weight. The dangerous mixture is between 5% and 15% when an explosive occurs[3]. The oxygen is depleted from the atmosphere by oxidation of coal, wood and others. The oxygen deficiency can be occurred as contaminant gas is liberated from the coal. In the coalmine[4], the low-cost portable devices have been used for detection of Methane gas. Various testing methods have been used to alert the miners about the security in the coalmine[5]. Wireless Sensor Network(WSN) plays an important role to collect the data from the environments like building, industrial, automation, home, shipboard, transport, etc. In a large scale networking environments, one of the most important factors is that it is self-organizing and interoperability between the sensors.

Correspondent author:
G.Varaprasad,
Department of Computer Science and Engineering, B.M.S. College of Engineering,
Bangalore-560019, Email: varaprasad555555@yahoo.co.in; Phone: +91-080-26622130-35

Many studies have shown that there are varieties of sensors used to collect the data efficiently. It transfers the data to the sink node. Thousands of sensors are expected in auto configuration and are operated to extend the period of time without human intervention. In many systems, it can be expensive or impossible to replace the batteries. In the WSN, there are three main functions such as sensing, controlling and actuating. Each node does several tasks in addition to the normal operation. Here, each node performs as a logical repeater to route the data packets[6].

This paper presents a sensor model to detect the harmful gases at coalmine. The paper is arranged as follows. Section II presents some of the existing models. Proposed method and its needs are discussed in section III. Simulation of the proposed model is presented in section IV. Section V discusses the results of the proposed method. Conclusion and further work are discussed in section VI.

II. EXISTING WORK

This section deals with some of the existing models. Simplified system, which is used to monitor the miners of underground in the coalmines[7]. It performs like an intelligent system to collect the valuable information about the accidents. Personal safety system was developed for the coalminers[8]. It accesses the data about the locations and personal safety of each coalminer over the network. It uses a flat-based routing to send the samples to the control room periodically. Drawback of this model is that it does not keep the record of historical information. In fact, it is suitable for small networks. These limitations make traditional database systems, which are not appropriate for WSNs.

A signal processing system was developed for detection of events using the low-power devices. It increases the system performance[9]. The signal processing architecture for WSNs was discussed in[10]. Implementation of parallel paths with the shared arithmetic elements for higher throughput at low clock rate was presented in[11]. Here, it uses the micro-sensor spectrum to analyze the samples and generate more number of control message packets over the network. The model has consumed more amount of bandwidth while forwarding the data packets.

III. PROPOSED WORK

The main focus of this work is to detect the Methane and Carbon Dioxide gases using the PLS41 and KGJ sensors at underground without disturbing the miners in coalmine. In this work, it uses two types of nodes namely regular and support. The support node has enough battery power(4000mAh) to transmit the data packets. It covers more graphical coverage area than the regular node. In fact, the regular node does not have enough battery power(800mAh) to route the data packets. The proposed model is shown in the figure 1. The regular nodes are equipped with the PLS41, and KGJ sensors for detection of Co_2 and CH_4 respectively. The regular node senses the data and forwards to the control room with the help of support node by considering threshold values of certain gasses as shown in the table 1.

III.A. Communication System

In this work, the proposed model uses IEEE 802.15.4 as a communication channel. The IEEE 802.15.4 is a wireless multi-hop network protocol and provides a low bit rate, low cost and less power consumption. The proposed model uses

MAC and PHY protocols. All the regular nodes give electrical output signals either in digital or analog form in order to perform the scanning operation. Each regular node senses the data periodically. The sensing data is analyzed with respect to the threshold values. If the data suggests any eventuality in nearby future, then the control room takes necessary steps to avoid/vacate the personnel. The sensing data is transmitted from the accident place to support node as explained in Theorem 1.

Theorem 1: A directed graph is $G=(V,E)$ with weight function $W:E\rightarrow V$, $p=\{v_1,v_2,v_3,v_4,v_5,v_k\}$ is a path from the accident place v_1 to support node v_k for i and j such that $1\leq i\leq j\leq k$. $p_{ij}=\{v_1, v_{i+1},v_j\}$ is a sub-path of p from the v_i to v_j. The p_{ij} is the shortest path from the vertexes v_i to v_j.

Proof:

Let us assume that a path is decomposed into $v_1\rightarrow p_{1i}\rightarrow v_i\rightarrow p_{ij}\rightarrow v_j\rightarrow p_{jk}\rightarrow v_k$ and $w(p)=w(p_{1i}) +w(p_{ij})+w(p_{jk})$. It assumes that there is a path $\breve{p}_{ij}$ from the v_i to v_j with a weight $w(\breve{p}_{ij})<w(\breve{p}_{ij})$. So $v_1\rightarrow p_{1i}\rightarrow v_i\rightarrow p_i\rightarrow v_j\rightarrow p_{jk}\rightarrow v_k$, is a path from the v_1 to v_k, whose weight $w(p_{1i})+w(\breve{p}_{ij})+w(p_{jk})$ is less than $w(p)$.

Theorem 2: $G=(V,E)$ is a weight function $W:E\rightarrow R$, if a path p form the support node s to control room v is decomposed into $s\rightarrow\breve{p}\rightarrow u\rightarrow v$, then the weight of a path is $\delta(s,v)=\delta(s,u)+w(u,v)$.

Proof:

Based on Theorem 1, p is a path from the s to u. Thus,

$$\begin{aligned}\delta(s,v) &= W(p)\\ &= W(\breve{p})+W(u,v).\\ &= W(s,u)+W(u,v).\end{aligned}$$

IV. SIMULATION RESULTS

In simulation, we have considered an area of 500 m X 500 m with a set of 330 sensors placed randomly. It used 300 regular nodes and 30 support nodes over the network. The simulation has carried out for 36 hours. The regular node powered with 800 mAh and 4000 mAh for support node. The proposed model uses the constant traffic bit rate. The simulation parameters are shown in the table I.

Detection of CH_4 is shown in the figure 2. Here, the red-box indicates the detection of the Methane gas position by considering threshold value when it reaches 1,000 PPM. The proposed model uses a set of predefined values. The density of Co_2 in the sampled area has compared with the set of predefined values. If the amount of Co_2 value in sampled area exceeds the maximum limit, then it makes an alarm accordingly. Detection of Co_2 is shown in the figure 3. The red-box indicates the position of Co_2. In the figure 3, the value of Co_2 is 5,243 PPM and the model makes an alarm over the network.

VI. CONCLUSION AND FUTURE RESEARCH WORK

In this paper, it presented a model called design and development of a sensor model for coalmines. The proposed model used fixed topology with the area of 500 m X 500 m. The proposed model automatically detects the Methane and Carbon Dioxide using the PLS41 and KGJ sensors. It sends the sensing data to the control room through support node over the network. The proposed model is an efficient method to reduce the control message packets over the network. However, it is observed that low transmission range will not provide communication among all the nodes. The proposed model has not considered channel interferences. In fact, it generated few control message packets over the network. In this work, it does not consider fault cases and packet loss but in real situation, there is a packet loss and fault cases in the network. To design a sensor model for coalmines with respect to the packet loss, bad-light and fire are further research work.

Authors' information

Srinivasa A.H recived BE(Computer Sciene and Engineering) from Bangalore University in 1999 and M.Tech(Computer Network and Engineering) from BMS College of Engineering, Bangalore in 2006. Currently he is working as a Lecturer in Dept of Computer Science and Engineering, Dr. Ambedkar Institute of Technology, Bangalore.

G.Varaprasad received B.Tech in Computer Science and Engineering from Sri Venkateswara University, Tirupati in 1999 and M.Tech in Computer Science and Engineering from B.M.S. College of Engineering, Bangalore in 2001 and PhD in Computer networks from Anna University, Chennai in 2004 and worked as a Postdoctoral fellow at Indian Institute of Science, Bangalore in 2005. Currently, he is working as an Asst.Professor in B.M.S. College of Engineering, Bangalore. His areas of research are routing algorithms, mobile communications and SNMP.

REFERENCES

1. Ben Van Well et al(2005), "An Open-Path, Hand-held Laser System for the Detection of Methane Gas, *J. Opt. A: Pure Appl. Opt.*, pp. S420-S424.
2. T. Iseki, H. Tai and K. Kimura(2000), "A Portable Remote Methane Sensor using Tunable Diode Laser", *Mea. Sci. Technology*, 11, pp. 594-602.
3. Wainner R. T, Green B. D., Allen M. G., White M. A., and J. Naper R.(2002), "Handheld, Battery-Powered Near-IR. TDL Sensor for Stand-off Detection of Gas Vapor Plumes", *Appl. Phys.* B, 75(2-3), pp. 249-254.
4. T. Iseki, H. Tai and K. Kimura(2000), "A Portable Remote Methane Sensor Using a Tunable Diode Laser", *Meas. Sci. Technol.* 11, pp. 594-602.
5. Powers P. E, Kulp T. J., Kennedy R.(2000), "Demonstration of Differential Backscatter Absorption Gas Imaging", *Appl. Opt.* 39 1440-8.
6. Jaikaeo C., Sridhara V., Shen C.(2006), "Energy Conserving Multicast for MANET with Swarm Intelligence", *In Proceedings of International Symposium on Wireless, Mobile and Multimedia Networks*, pp. 7-11.
7. Jeffrey P. M., Vaduvur B., and Wen-mei H.(2001), "A Power Controlled Multiple Access Protocol for Wireless Packet Networks", *In Proceedings of IEEE INFOCOM*, pp. 219-228.
8. L. M. Kirousis, E. Kranakis, D. Krizanc, and A. Pelc(2000), "Power Consumption in Packet Radio Networks", *Theoretical Computer Science*, vol. 243, no. 1, pp. 289-305.
9. D. D. Wentzloff, B. H. Calhoun, R. Min, A. Wang(2004), "Design Considerations for Next Generation Wireless Power-Aware Micro Sensor Nodes", *In Proc. of International Conference on VLSI Design*, pp. 361-367.
10. G. J. Pottie and W. J. Kaiser(2000), "Wireless Integrated Network Sensors", *Journal of ACM*, Vol. 43, pp. 51-58.
11. A. Mita, S. Takahira(2002), "Damage Index Sensors for Smart Structures", *In Proceedings of World Conference on Structural Control*,Vol.2,pp.29-34.

Table I. Threshold values of gases.

List of gases	PPM	MG/M3
Carbon dioxide($C0_2$)	5,000	9,000
Methane(CH_4)	1,000	800

Table I. Simulation parameters.

Number of the support nodes	10
Number of the regular nodes	200
Simulation time	6 hours
Traffic type	CBR
CBR packet size	500 bytes
Transmission range of support node	250 m
Transmission range of regular node	150 m
Channel capacity	128 Kbps
Regular node battery with	5 V
Support node battery with	10 V

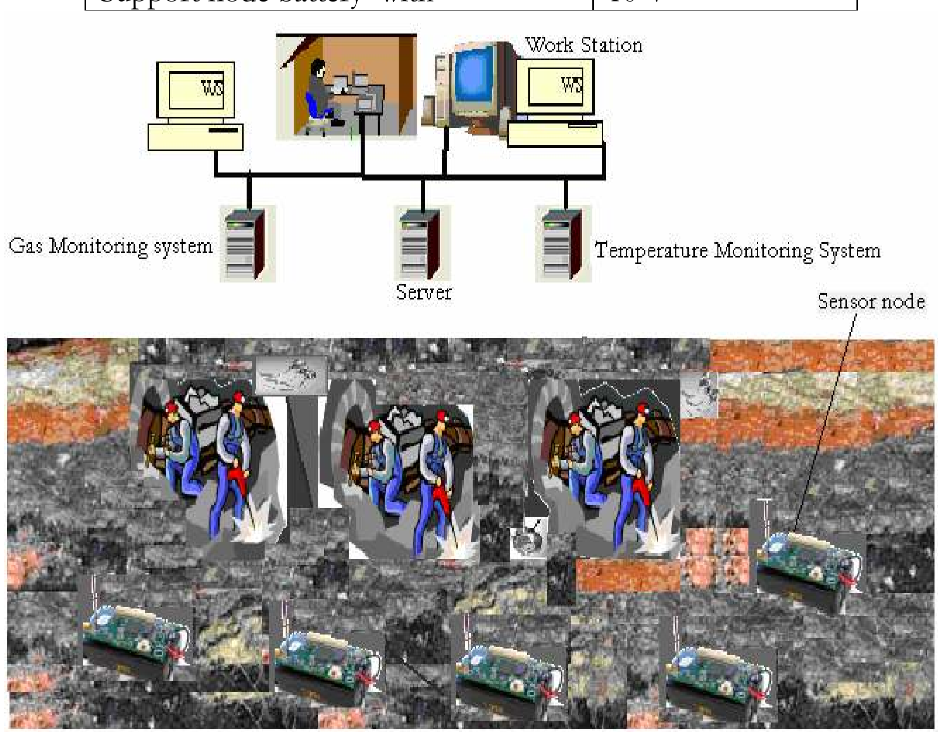

Figure 1. Proposed method.

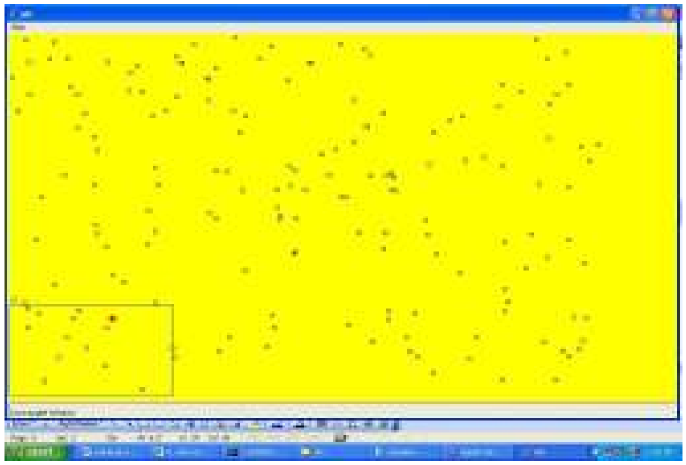

Figure 2. Detection of CH_4.

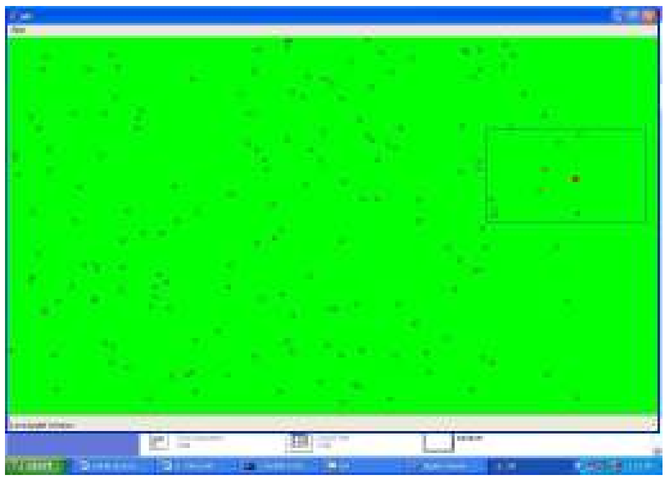

Figure 3. Detection of Co_2.