Networkable Carbon Monoxide Control System for Nomadic Indoor Cooking Environment

[1] James Agajo, [2] P.O. Idogho, [3] H.F. Rashvand,

[1] Department of Electrical and Electronic Engineering, Auchi Polytechnic, P.M.B.13, Auchi, Edo State, Nigeria
[2] School of Information and Communication Technology, Auchi Polytechnic, P.M.B.13, Auchi, Edo State Nigeria
[3] Advanced Communication Systems, University of Warwick United Kingdom

Keywords: CO Pollution, WSN, Health Control, Monitoring

Abstract

In this paper we address the life-threatening problem of indoor CO air pollution generated by traditional indoor cooking practices in many local communities of sub-Sahara African countries. Using low cost smart wireless sensors we can provide an effective low cost life saving solution for many people and young lives today. Taking on a case study for using networkable wireless sensors we propose a new infrastructure to measure the amount of indoor carbon credit discharged during the cooking period with a view to establishing a new monitoring and control process of sending alerts through wireless channels to the fusing points. The work also reports a new networking design, practical issues and battery life management upon the measurements and simulation results.

1 Introduction

As we are celebrating our IT and global village era in many places on earth due to many practical obstacles such as remoteness and slow-changing people's old habits many young lives are seriously in danger of CO poisoning whilst low cost smart wireless sensors can provide an effective, low cost and superior interim solution and help many communities to help themselves.

The problem of indoor CO air pollution generated from poorly burning fuels such as wood has been known for centuries and most industrial societies have overcome this problem by deploying advanced cooking methods and securing any possible risks. However, many remote families and isolated societies still continue to use this dangerous cooking method without understanding the potential risks they are imposing on their own and their children's lives. Life is too precious to put one's at risk for whatever the reason. We, therefore, must do our best to use the upmost effort and ability to break away any possible bottlenecks by denial of technology, availability, economy, infrastructure or any other negligence or inhuman behaviour.

The main problem stemmed from the fact that most of under developed societies are becoming more and more dependent on developed societies to solve their problems whilst such local problems for many reasons have never been resolved by the developed societies: (a) do not see the problems as they are facing us; (b) old problems solved once and moved on, no need to reconsider; (c) industries may be aware of the problem but the scale of the market is too short-term to justify any significant business case; (d) complexity of dealing with under-developed remote societies does not trigger any interest and (e) aid-workers and international organisation cannot help at this level due to their complex multi-level operating systems. This means problems of this kind must be investigated and resolved by local researchers and resolved by local industries, where the local governments should show their usefulness and exercise their capabilities.

We know that low cost smart sensors are abundantly available throughout the world and CO sensors are one of them. That is, with the arrival of mass produced smart sensors, the task of monitoring has improved extensively in cost and availability [1]. With the arrival of embedded technology sensor systems we are taking on huge complexities and for many sophisticated innovative applications all that remains to do is proper design and optimization [2,3].

In order to solve our problem we need to address it at system level. That is, we know there are already many low cost and reliable CO detectors on the market but no suitable and practical solutions are available as yet to save those imminently at risk. This study, therefore, relies on the use of smart wireless sensors, which tend to develop an easy-to-deploy CO detection useable for low-cost indoor air pollution monitoring for sub-Sahara's African township populations.

The development task of this monitoring platform design using new wireless sensor networking devices is a new deployment practice carrying a significant degree of novelty by being a unique task, which many experts fail to recognise. We, therefore, need to go beyond pure research by integrating many rich technologies including wireless sensing, data acquisition, networking and data distribution plus adoption of a new control multiplexing mechanism to monitor and control the operation via a supervisory management centre. For doing this our network topology consists of the sensor nodes to collect raw data from the sensing points sent to a command centre via radio transmitter and the sink nodes accessed through some data fusion nodes in the network.

2 Indoor air pollution

In this study we investigate use of spatially distributing autonomous sensors to *monitor* the air condition disparity in the household cooking practice in poor rural dwellers. We look at real life-threatening issues facing people which need urgently to be attended to. These people use fuel wood (firewood) extensively, with a particular reference to poor rural dwellers in sub-Saharan Africa. Beside the health effect the sub-Saharan region is presently hit with the massive effect due to continuous felling down of trees. Due to this activity the desert is encroaching fast at a rate of 500 metres per year

and we are gradually losing our green habitats leaving the population vulnerable to the various implications arising from the absence of green vegetation [2].
Indoor air pollution (IAP) is regarded as one of the most important factors affecting people's quality of life. In Sub-Sahara Africa, most areas have already some networking infrastructure and capability of monitoring atmospheric carbon credits in highly populated areas, which require continuous measurement in modern houses but none for remote and isolated inhabitants. They need controllable sensors so that an accurate estimation on the amount of CO discharged into the indoor atmosphere from the household cooking can be monitored.

What is carbon monoxide? Carbon monoxide or CO is a colourless, odourless and tasteless gas. Due to this fact, it is very hard to detect the presence of CO in your environment. It is, however, imperative that the CO levels in your home are monitored. Even at relatively low levels, CO is poisonous because it rapidly accumulates in the blood thereby depleting its ability to carry oxygen. In many cases CO poisoning result in death [5].

2.1 CO Emission

Wood is mainly just carbon, hydrogen, and oxygen: [C+H_2O] combustion, $C + H_2O + O_2 \rightarrow CO_2 + H_2O +$ heat, as shown in Figures 1 and 2, and would create an incomplete combustion condition then unavoidably some of the wood carbon is not completely combusted into CO_2 and biomass burning emits many products of incomplete combustion. Then, the inhaled CO binds with haemoglobin flow and dissolved in the blood, displacing O_2, forming carboxyl haemoglobin [COHb]. Then, this CO penetrates into the alveolar region where it can be absorbed into the blood stream.

Figure 1: Usual open fire indoor cooking practice

Figure 2: Open wood fire fuel producing massive CO

At what level does carbon monoxide become toxic? The answer is quite complicated. It is much more dangerous for small children than adults. For healthy adults the level of CO becomes toxic when the density of the CO reaches one's effective level when beyond this level the person starts to feel lack of total coordination due to suffering symptoms from the exposure. A mild exposure of over 2-3 hours, e.g., a CO level between 35 ppm (parts per million) and 200 ppm will produce flu-like symptoms such as headaches, sore eyes. However, at higher levels of over 35 ppm with continuous exposure over eight hours period results in a runny nose. Medium exposure (a CO level between 200 ppm to 800 ppm) will produce dizziness, drowsiness and vomiting in as little as 1 hour. This level of exposure is deemed life threatening after some three hours. Extreme exposure (a CO level of 800 ppm and higher) will result in unconsciousness, brain damage and eventually death in as little as a few minutes. Guidelines state that the maximum exposure over an eight-hour time period should be maintained below 35 ppm. Figure 3 shows some death rate estimated values, where PM10 indicates that the Particulate Matter, carbon size, is 10 [4].

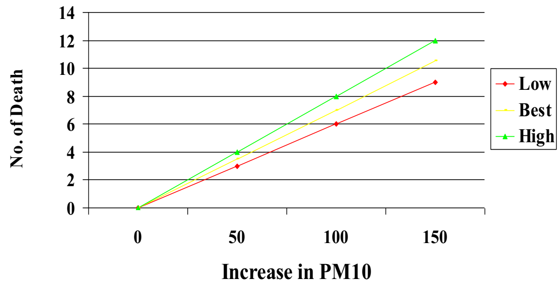

Figure 3: Death rate caused by CO emission

3 Electro-chemical CO detection

Electrochemical gas sensors are detectors that measure the concentration of a target gas by oxidizing or reducing the target gas at an electrode and measuring the resulting current [4]. The measurement of carbon monoxide level is produced using a CO chemical sensor. The sensor commonly used for detecting CO is a classic chemical reaction measuring device, which works with the gas being diffused into the sensor through the back of the porous membrane to the working electrode where it is oxidized or reduced. This electrochemical reaction results in an electric current that passes through the external circuit. In addition to measuring, amplifying and performing associated signal processing functions, the external circuit maintains the voltage across the sensor between the working and counter electrodes for a two electrode sensor or between the working and reference CO, in the present of O_2, being converted into CO_2: as the voltage drops across the resistor is measured using Ohm's law ($V=IR$), where the voltage is directly related to the concentration of the CO in the incoming gas, see Figure 4, which shows a schematic of a Carbon Monoxide sensor.

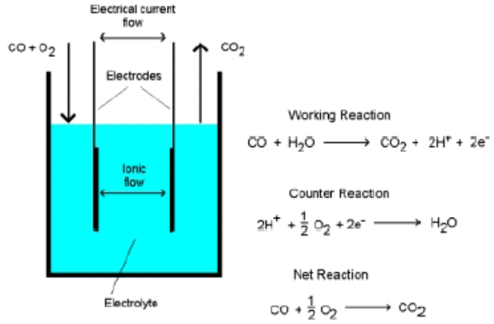

Figure 4: Electro-chemical carbon monoxide sensor [4]

4 Networking system structure

Although the design can be helpful at a small scale when an alarm is triggered warning the user of a danger in practice, considering the level of technology today, it does not provide innovative enough action to activate any national or international deployment due to the facts such as (a) most people using such techniques show very little appreciation of the technology; (b) they are too poor to afford financing any individually based equipment and (c) being technically naïve would not be able to maintain a fully operational and fully functional device if they had one. We therefore propose a networkable controlling system where a remotely supervised centre is an existing nearby Community Tele Centre (CTC) [5], a health-centre or a shop or office elsewhere connected through wireless where the Internet can supervise the monitoring operation and send help when required. Considering the power consumption of active devices a massive multiplexing system can also be integrated into this supervisory network to help to enhance the operational life of the batteries if these devices are put to sleep most of the time and in operation at a small fraction of the time only.

The designed system in here for collecting data, estimate and analysing it is build around wireless sensors for monitoring both the carbon emission as well as the temperature in household cooking environment can also provide an enhanced supervisory control and data acquisition, with a view to collecting data processed and arranged in a database in real-time via a computer using a handheld mobile Graphic User interface, The system also put into cognisance the creation of a dynamic graph plotter as shown in Figure 5.

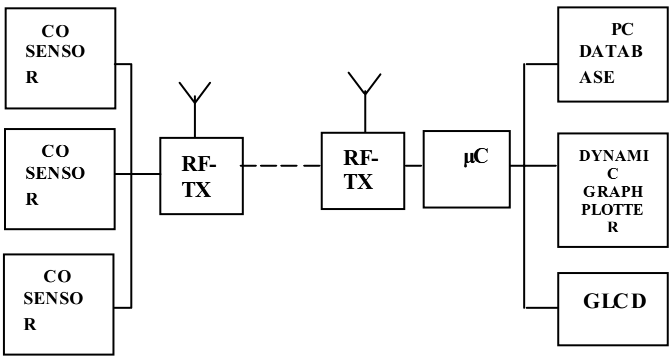

Figure 5: Block Diagram Wireless Smart System

At the controlling level, in order to optimise the system's overall operation for cost, energy and scheduling a wirelessly connected sensor network, using a model similar to that shown in Figure 6, characterized by the following L variables, can be adopted:

$$\{S[n]\}n\geq 0 = \{(S1[n], S2[n], . . . , SL[n])\}, n \geq 0, \ldots \quad (1)$$

Here, n is the time stamp to characterize a sequence of random event [6,7].

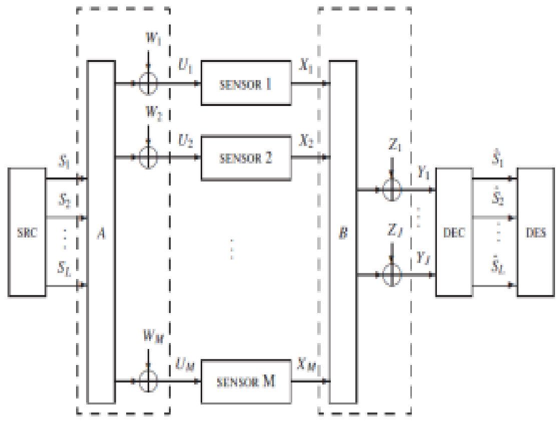

Figure 6: Networking structure of sensor node multiplexing

Fortunately, our protocol for adopting this system is simple and straightforward resulting in very simple transceiver systems, which lead to very little RF interference. Also largely due to the fact that sensor nodes have very low duty cycles, transmitting only occasionally and sending only small amounts of data [8]

In order to control the network with hundreds of tiny sensors dropped in a rather small and dense township geographical area, such as that shown in Figure 10, a better design can be easily achieved by using a low complex massive multiplexing structure, shown in Figure 7 [9,10].

4.1 Address allocation table

This is configured using a suitable coverage of all users being a narrowband wireless metropolitan area (WMAN), a wireless multi-hop local area network (WLAN) or a wireless wide area network (WWAN), the two dimensional addressing and round-robin style scheduling system would help with two main energy demanding parts of the process:

- Minimum timely hand-shaking and associated communication consumption;
- The reduced internal processing conserves the battery use of a sensor node

Plus the fact that this multiplexing method would require a much smaller memory for storing, handling and processing sensing data that would reduce the complexity of the sensing device and therefore associated overall cost [11,12,13].

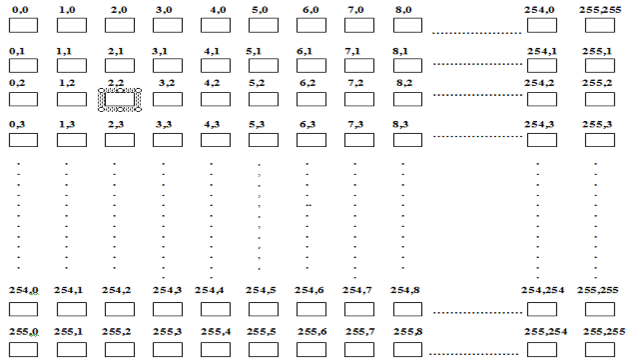

Figure 7: Typical address allocation table for the required massive multiplexing/addressing configuration [14,15,16].

5 Experimental and simulation results

In the first phase of the project, in conjunction with running corresponding simulations on the computers the research team have been setting up a few experimental sensors in various locations in the target area where we can test the operation, measure the signals and energy consumption of the devices. One of experimental areas of the project is to examine the Ampere-hour unit for the batteries. Here we have two classes of devices in the network, the sensor nodes or source nodes (SN) and switching, interworking or intermediate nodes (INT). For both we use a standard mote based battery of 1027 AH, where for typical 3.7V use they store 3.8 WH of energy. Supporting the typical current consumption of:

- RX mode: 19 mA
- TX mode: 23 mA
- Sleep: 2 mA

In this system, data received from a respective source, transmitted from the source node to a collection point, goes through a data discovery process until a desirable message is recovered and collected and delivered into a database. Due to the lack of control in capturing the right sample of the emitting gases entering the sensor for an accurate measurement of the CO content, each data is then analysed upon an adaptive mathematical model for an adequately established model, in this case the variable, where we are measuring carbon monoxide, a statistical model that represents the behavioural cooking pattern in local communities, in this case for Nigeria [17,18,19].

6 Some results for discussion

Graph in Figure 8 compares the source and intermediate node in terms of Ampere Hour plots for active and sleep conditions of the batteries. Figure 9 is the JAVA/ORACLE interface for data collection in the database. Figure 10 shows System output of CO Emission. Figures 11 and 12 shows map of two test bed pilot areas for deploying the sensor nodes.

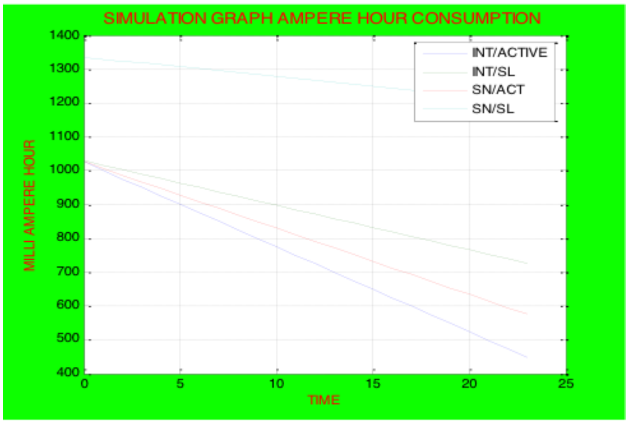

Figure 8: Graph of Ampere Hour consumption for all 4 simulations option

Figure 9. Data base JAVA/ ORACLE Interface data collection

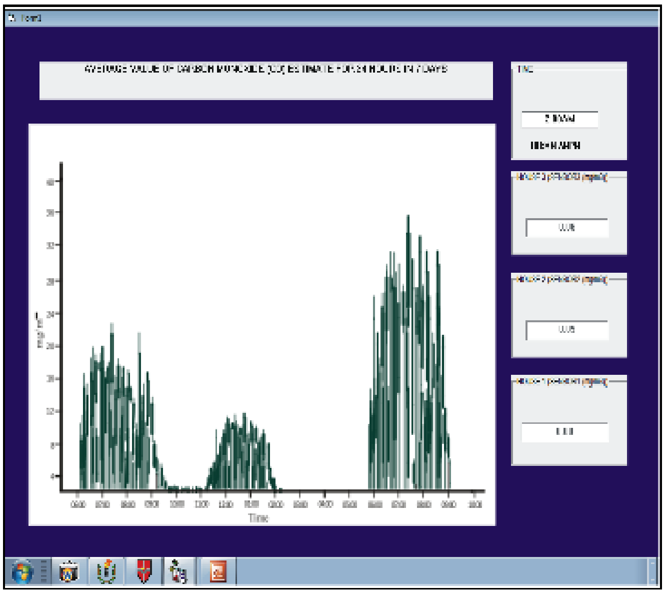

Figure 10: System output of CO Emission day 2

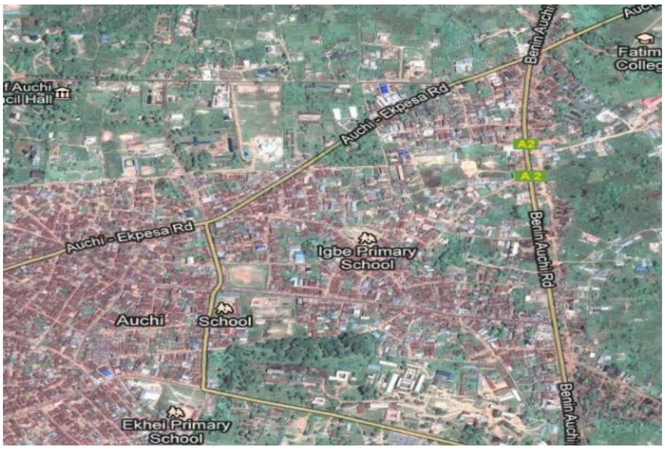

Figure 11: Test bed 1, map area of deployment of the nodes

Figure 12: Map area of deployment of Wireless Sensor nodes Test bed 2

7 Conclusions

Adopting a sleep mode integrated massive multiplexing design for improved CO Electro-Chemical sensor development followed by the test, simulation and measurement of detecting CO level beyond 35 ppm for generation an alarm and sending a message to the user can save many lives. The new system level deployment design of CO monitoring networked sensor system features simplicity, low-energy and low-cost interactive remote monitoring and control solution shown to be an ideal and practical solution for the existing African sub-Sahara's poisonous indoor traditional cooking problems. The battery life remains a vital component of the system in operation, where inclusion of a sleep mode scheduling enables a significantly extended battery life.

This work was carried out in Auchi, Edo state (south-south) Nigeria Africa.

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