# New Challenges in Air Quality Sensing using Robotic Sensor Network

Nyayu Latifah Husni, Ade Silvia, and Siti Nurmaini

***Abstract* —** Air pollution is one of big problems in our earth that should be paid more attention. This has led the researches of air quality smart monitoring using static and mobile sensors. Taking inspiration from this, we proposed a robotic sensor Networks (RSNs) which is inexpensive and utilizes simple sensors. To increase the reliability of the gas sensing of the RSNs, we use MQ 6 gas sensor that can detect the source of the gas rapidly, it does not only respond to the natural gas but also the combustible one.

***Keywords*—** Air Quality Sensing, Robotic, Sensor Networks, Sensing Technology.

## I. Introduction

AFTER the industrial revolution, the burning of fossil fuels and many human activities have significantly increased the concentration of carbon dioxide (CO2) year by year. It is widely concluded that the increase of the CO2 concentration is a major reason to cause global warming, which can affects the environmental air quality. The output of burning sometimes is incomplete that produces carbon monoxide (CO). Carbon monoxide is a colorless, odorless, and tasteless gas which is slightly lighter than air. Differ from CO2, carbon monoxide has poisonous potential because can make a strong bond with blood pigment (Hemoglobin). This problem overcoming has led to the investigation of implementing sensor networks to monitor environment air quality.

In getting the information of the environment air quality, we need some sensors that can convert the environment physical phenomenon (in this case temperature, humidity, and pollutant concentration) into electrical signals. As such, sensors represent part of the interface between the physical world and the world of electrical devices, such as computers.

In recent years, sensors have received people's attention as one of the important devices in electronic systems and enormous capability for information processing has been developed within the electronics industry. Of all sensors, gas sensors and light sensors have been most actively studied [1]. Gas sensors are defined as a device that can substitute for human olfaction, and there are many researches being conducted to monitor air pollution by using these electronic nose.

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The process of monitoring was done using several stationary monitoring stations by implementing sensor networks (SNs) [2]. The development of sensor networks requires technologies from three different research areas: sensing, communication, and computing (including hardware, software, and algorithms).

Being used in the abnormal weather and areas, mobile sensor networks are more reliable than static one. [3]. Mobile platform can give great contribution in monitoring and collecting the data of air quality in the area that cannot be attended by the humans, i.e. in the street canyon where it is too dangerous for the human to get in.

Due to the moving capability of mobile SNs to the locations that meet sensing coverage requirements, they become an important area of research. Multi robots that autonomously monitor different environments cooperate with other systems and collect data. They can act as interfaces to SNs solutions and also enhance them by providing important benefits such as sensor deployment, calibration, failure detection and power management [4].

Choosing and positioning correct sensors to robotic wireless network (RSNs) are much more challenged. [Siti Nurmaini, Low Cost Robotics Sensor Network Platform for Monitoring of Air Quality] discussed the usage of 5 distance sensors and 2 gas sensors in monitoring the air quality. The sensors are placed: 2 sensor in the LEFT (0˚ and 45˚), 1 sensor in the MIDDLE (front side 90˚), 2 sensors in the RIGHT (135˚ and 180˚). 2 gas sensors are placed in the front side of the robot. In this paper, the proposed prototype Robotics Sensors Networks (RSNs) used in monitoring the air quality are equipped with 8 distance sensors and 1 gas sensor. The gas sensor used is MQ 6 that has lower conductivity in clean air and sensitivity to propane and butane and also to other natural gases, low sensitivity to cigarette smoke and alcohol [5]

MQ 6 is one of solid state gas sensors which are used widely [6] due to their advantages, like small sizes, high sensitivities in detecting very low concentrations (at level of ppm or even ppb) of a wide range of gaseous chemical compounds, possibility of on-line operation and, due to possible bench production, low cost. [7].

## II. Sensing Technology

Current sensor networks (SNs) can exploit technologies not available 20 years ago and perform functions that were not even dreamed of at that time. Sensors, processors, and communication devices are all getting much smaller and cheaper. Table I compares three generations of sensor nodes.

Sensing technology has been widely investigated and utilized for gas detection. Due to the different applicability and inherent limitations of different gas sensing technologies, researchers have been working on different scenarios with enhanced gas sensor calibration. Gas sensing technology has become more significant because of its widespread and common applications in the following areas: (1) industrial production (e.g., methane detection in mines); (2) automotive industry (e.g., detection of polluting gases from vehicles); (3) medical applications (e.g., electronic noses simulating the human olfactory system); (4) air quality supervision (e.g., detection of carbon monoxide) ; (5) environmental studies (e.g., greenhouse gas monitoring). [9].

TABLE I
THREE GENERATION OF SENSOR NODES [8]

| | 1980's – 1990's | 2000's – 2003's | After 2010 |
|---|---|---|---|
| Manufacturer | Custom contractors, e.g., for TRSS | Commercial: Crossbow Technology, Inc. Sensoria Corp., Ember Corp. | Dust, Inc. and others to be formed |
| Size | Large Shoe box and up | Pack of cards to small shoe box | Dust particle |
| Weight | Kilograms | Grams | Negligible |
| Node Architecture | Separate sensing, processing, and communication | Integrated sensing, processing and communication | integrated sensing, processing and communica tion |
| Topology | Point-to-point, star | Client server, peer to peer | Peer to peer |
| Power Supply lifetime | Large batteries; hours, days and longer | AA batteries; days to weeks | Solar; months to years |
| Deployment | Vehicle-placed on air drop sinle sensors | Hand-emplaced | Embedded, "sprinkled" left behind |

*TLV (Maximum exposure in 8 h period in 40 h work week)
**CFC(Chlorofluorocarbon/Freon).

Gas sensor devices are divided into three groups depending on the technology applied in their development: Solid State, Spectroscopic and Optical. Solid state sensors are preferred than spectroscopic and optical because they have fast sensing response, are easy to be implemented and need only low cost.

TABLE II
ENVIRONMENTAL STANDARD CONCENTRATION AND THRESHOLD LIMIT VALUE (TLV) OF AIR POLLUTION [11,12]

| **Pollutants** | **Concentration** | | |
|---|---|---|---|
| | **Environmental** | **TLV*** | **Request of sensors** |
| $NO_x$ | Below 0.04-0.06 ppm (daily average) | NO2 : 3 ppm | |
| | | NO : 25 ppm | 0.01-0.3 ppm |
| $CO_2$ | - | 5000 ppm | 200-400 ppm |
| CO | 35 ppm (1 h average) | 50 ppm | 0.1 – 10 ppm |
| HCHO | - | 1 ppm | - |
| $SO_2$ | Below 0.04 ppm (daily average) | 2 ppm | 0 – 2 ppm |
| $NH_3$ | - | 25 ppm | - |
| $O_3$ | Below 0.06 ppm (1 h average) | 0.1 ppm | 0.05 ppm |
| CFC** | - | - | 20 ppt |

Solid State gas sensors are semiconductor metal oxides sensors based on the transduction principle of the physical and/or chemical properties of sensing materials when exposed to various gas atmospheres. The detection principle of resistive sensors is based on change in resistance of a Semiconductor Metal Oxide (SMO) thick/thin film upon adsorption of the target gas species to be detected. [10]

Environmental standard concentration and threshold limit value for six important gases of air pollution are listed in Table II. Some information about gas sensors on the base of most familiar metal oxides and technological peculiarities of these sensors fabrication, which can be used for such selection,is presented in Tables III.

TABLE III
MAIN ADVANTAGES AND DISADVANTAGES OF WELL-KNOWN METAL OXIDES FOR GAS SENSOR APPLICATION [13]

| Materials | Advantages | Disadvantages |
|---|---|---|
| $SnO_2$ | High sensitivity, Good stability in reducing atmosphere | Low selectivity, Dependence on air humidity |
| $WO_3$ | Good sensitivity to oxidizing gases, Good thermal stability | Low sensitivity to reducing gases, Dependence on air humidity, Slow recovery process |
| $Ga_2O_3$ | High stability, Possibility to operate at high temperatures | Low selectivity, Average sensitivity |
| $In_2O_3$ | High sensitivity to oxidizing gases, Fast response and recovery, Low sensitivity to air humidity | Low stability at low oxygen partial pressure |
| CTO ($CrTiO_x$) | High stability, low sensitivity to air humidity | Average sensitivity |

## III. ROBOTIC SENSOR NETWORK DESIGN

### A. *Sensor System Design*

Based on the fact that the most common sensing materials are metal oxide semiconductors, which provide sensors with several advantages such as low cost and high sensitivity. In our work, we use MQ-6 as the sensing of the gas. MQ 6 is made of $SnO_2$ material which has lower conductivity in the air. The structure and configuration of MQ-6 gas sensor is shown as **Fig. 1**, MQ-6 sensor composed by micro $AL_2O_3$ ceramic tube, Tin Dioxide ($SnO_2$) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-6 have 6 pin ,4 of them are used to fetch signals, and other 2 are used for providing heating current.

### B. *Architectures of RSNs*

In our proposed work, we used low cost robotics sensor node and low cost microcontroller, The architectures and the algorithms that we use in this proposed RSNs are based on the previous researches. The architecture consists of three layers, namely: node layer, client layer and server layer. The navigation strategies will be done using the combining of Interval type 2 Fuzzy Logic and Particle Swarm Optimization (PSO) (IT2FL-PSO).

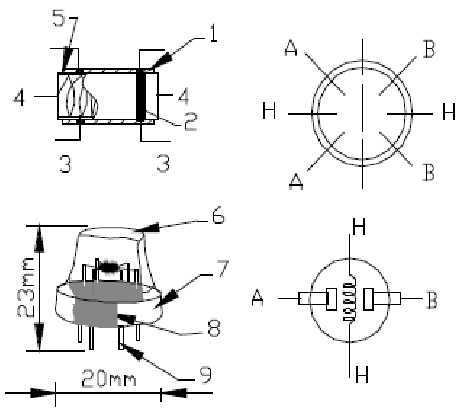


Fig 1 Configuration of MQ 6

Our architecture for robot control is a layered architecture similar to the one proposed in [Siti Nurmaini, Low Cost Robotics Sensor Network Platform for Monitoring of Air Quality]. The complete system architecture of a robotics sensor network consists of a group of static and mobile sensor nodes, a base station, upper communication network infrastructures and clients (Fig 2). The RNs here is a mobile sensor node that has the capabilities of connecting a base station to another network, such as internet.

As mentioned above, the architecture consists of three layers: node layer, server layer and client layer. The node layer are filled by all the static or mobile sensor nodes. The server layer includes a personal computer or a single board computer that runs server software. The client layer includes local clients and remote clients. The server layer and the client layer communicate each other and form a typical example of internet.

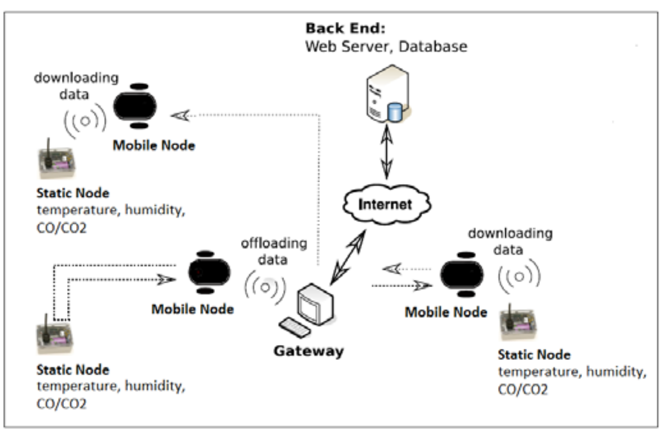


Fig. 2 Robotic sensor networks (RSNs) architecture

The communication of mobile node will be done using microcontroller AT Mega 16 and X-bee Pro (Fig 3). Xbee-pro is RF module designed using IEEE 802.15.4 standard. Its tiny form and low consumption power, 3.3.V makes it be reliable. The communication operates using frequency 2.4 GHz and can be done wirelessly or serially.

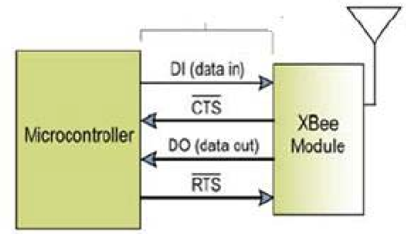


Fig. 3 Mobile node comunication

### C. *Position of MQ 6 Sensors*

The sensor nodes used in this proposed work are divided into two parts, one is for static and the other is for mobile. The humidity and the temperature sensors will be placed on the static nodes to save the energy of the mobile power.

For the mobile node we used the robot as the media of the system. The position of the sensors placed in this robot is shown in Fig 4. The 8 distance sensors used are placed in the position of wind points. It is meant to decrease the error of the robot's movements. Using the 8 sensors can make the robot's $360^{0}$ movement be easier.

The MQ 6 gas sensor is placed in the middle of the robot. Due to its ability of sensing in the further range, we can save the cost of sensors by using only one gas sensor in each robot.

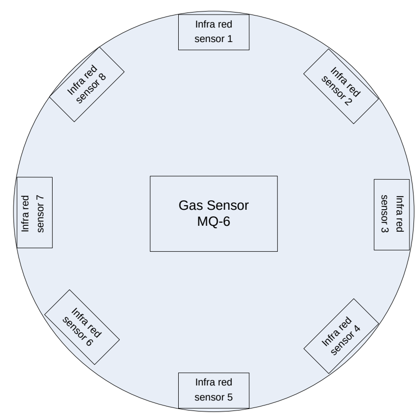


Fig. 4 Position of the sensors

## IV. Conclusion And Future Work

This paper describes the prototype design of robotic sensor networks in monitoring the air quality using gas, temperature, and also humidity sensors. The mobile node will be equipped with gas sensor that can detect the gas sources. The gas sensor used is composed by micro $AL_2O_3$ ceramic tube, Tin Dioxide ($SnO_2$) sensitive layer, measuring electrode and heater that are fixed into a crust made by plastic and stainless steel net. The media of the mobile node is mobile robot that has 8 distance sensors. The humidity and the temperature sensors will not be placed on the mobile node in order to save the energy of the robot.

On the future, the robot will be equipped with other gas sensors that are compatible for some gases in order to increase the accuracy of the air quality data. The robot will be also be equipped with the tank wheels that can travel on the difficult and steep road. Besides that the robot will also be equipped with the autonomous and manual mode in order to increase the reliability of the robot when it walks on the difficult area.

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