Wireless Sensor Networks for Environmental Monitoring: A Review

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Abstract — *The need for Wireless Sensor Network (WSN) has been on the increase because of the rapid development and miniaturization of sensor devices and the recent advances in wireless communication technologies. This paper reviews the subsystems of an environmental monitoring sensor node. It discusses indoor, outdoor and greenhouse environmental conditions. The electrochemical sensors were discovered to be highly suitable for outdoor monitoring of carbon monoxide. For indoor monitoring of temperature, it was discovered that the Resistance Temperature Detectors made of platinum are the most preferred while the capacitive type sensors are best suited for humidity monitoring. For greenhouse gases, infrared sensors are best for measuring carbon dioxide and methane gas.*

Keywords — *WSNs, sensor, monitoring, environment*

I. INTRODUCTION

A sensor is a device, module, machine or subsystem whose purpose is to detect or respond to a physical property, event or changes in its environment and send the information to other electronics which may record, indicate or otherwise respond to it [1]. A Wireless Sensor Network (WSN) is a collection of sensor nodes that are organized into a cooperative network. It is also an instrument used for gathering information about the natural world. Its technology has introduced a low-cost, low-power featured hardware containing microcontrollers, storage memory, power supply, one or more sensors [2]. Wireless sensors have comparative advantages over conventional sensors. They perform more functionalities than conventional sensors because of the use of microcontrollers and hence adopted for applications that are more complex. Table 1 compares wireless and conventional sensor types.

Table 1: Comparison Between Conventional Sensors and Wireless Sensors

Conventional Sensors	Wireless Sensors
They do not make use of microcontrollers	They use microcontroller to perform their functions. Therefore requires to be programmed.
Have high maintenance cost	Low maintenance cost
They can test only one environmental factor	They can sense more than one environmental factor
They don't have a node, just a single sensor	They comprise of several sensor nodes

II. WIRELESS SENSOR NETWORK BASED ENVIRONMENTAL MONITORING SYSTEMS

The existing WSN based environment monitoring systems are usually deployed in three different categories or environment depending on their use. These categories are the indoor, outdoor and greenhouse.

III. COMPONENTS OF AN ENVIRONMENTAL MONITORING SENSOR NODE

Sensor nodes are small, low in cost and have short communication range. The sensor node is the primary component of any WSN .Figure 1 shows the block diagram of the subsystems that make up a sensor node.
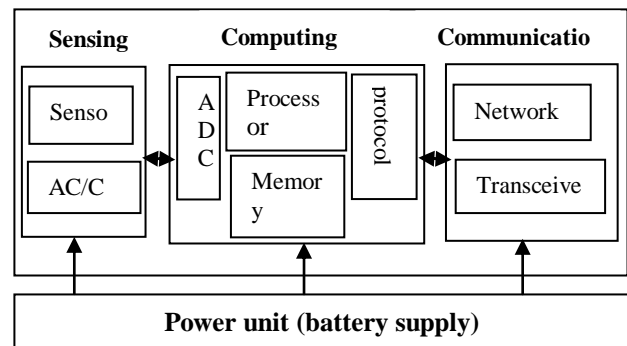

Figure 1: Sensor node Architecture [3].

A sensing subsystem
This subsystem consists of a wide range of sensors which measure environmental conditions such as temperature, gases such as carbon dioxide, carbon monoxide etc. The sensors collect and send data to the base station, which is the task manager of the network. The transmitters collect process and transmit the gas concentration levels, temperature and the sensor's location signals in real time.

The most common outdoor environmental gas is carbon monoxide (CO) which can be dangerous to human health if not detected and controlled. The major classifications of CO gas sensors include opto-chemical, biomimetic, electrochemical, semiconductor, and portable and wireless type sensors. Opto-chemical sensors are the lowest cost but offer the lowest level of protection. Biomimetic sensors darken in the presence of CO proportional to the amount of CO in the surrounding. They have high cost and mostly preferred in sensitive areas. Semiconductor CO sensors demand high power and usually have limited lifespan. Portable sensors offer real time measurement of CO but are expensive. Wireless sensors are normally adopted for remote and distant applications. Electrochemical sensors have shown some advantages over other types in that they have a highly accurate and linear output to carbon monoxide concentration. It also requires a minimal operating power and has a long lifespan.

Table 2 compares some specialized sensors used to detect carbon monoxide gas in the environment. First alert CO sensor has shown longer life, large and readable display when compared to the other sensors.

Table II: Comparison of Common Examples of CO Detectors [4]

Brand	Nest Protect	Leeo Smart Alert	Kidde CO Alarm	First Alert CO710
Sensor type	Electro chemical	Alerts through phone	Electro Chemical	Electro chemical
Source of power	Battery (10 year life)	AC mains outlet	Battery (6-12 months)	Battery (10 year life)
Additional functions	Smoke detector	Night light	Digital display	Digital display, ambient room temperature
Pros	Smart features and easy set up	Cheap to add smart function	Free standing; used on a wall or flat surface	Modern design, large with digital display
Cons	High price	May not be cost efficient	No app Connectivity	No app connectivity
Best for	Specialized CO detection	Homes	Households that want simple CO detectors	Larger digital display to read easily

The two common indoor environmental conditions include humidity and temperature. The various types of humidity sensors are capacitive, resistive, semiconductor, surface acoustic waves, optical sensors. The best-known humidity is the capacitive-type sensor. This is because water has an abnormally large dielectric constant and changes in relative permittivity by adsorption of water provide a simple detection mechanism [5]. Capacitive type sensors also have low power consumption, good linearity and wide range RH detection [6]. However, it has a complicated fabrication process, which is its major drawback. Resistive sensors are highly sensitive, low cost, low power consumption and easier to fabricate. The most frequently used materials for the fabrication of humidity sensors are metal oxide, polymers and carbon-based materials [5]. Table 3 compares some specialised humidity sensors.

Table III: Comparison of Common Examples of Humidity Sensors [7]

Brand	Elertus Smart Sensor	SensorPush	ConnectSense Temp and Humidity
Connectivity	WiFi	Bluetooth	WiFi
Notifications	Alerts	Android and iOS apps	Phone Calls, text message, email
Additional features	Runs on two AA batteries	Temp range (40°F - 140°F)	Runs on battery or 5V USB power.

Table 4 also compares the different sensors used for temperature measurement. Thermistors provide a very high resistance at low temperatures. Semiconductor based sensors are placed on integrated circuits. They have the slowest responsiveness, lowest accuracy with the narrowest temperature range. [8]. Resistance Temperature Detectors (RTD) made from platinum are most preferred because they offer linear output hence higher accuracy [9]. They are however, the most expensive of the temperature sensors.

Table IV: Comparison of Different Types of Temperature Sensors [10]

Parameters	RTD	Thermistor	Integrated silicon
Temperature range	-250 to 900°C	-100 to 450°C	-55 to 150°C
Accuracy	±0.5C	±0.1C	±1C
Sensitivity	Low	High	Highest
Form of output	Resistance	Resistance	Voltage, current, digital
Excitation	Current	Voltage	Supply

	source	source	voltage
Cost	Low	Low	Low to moderate
Linearity	Fairly linear	Exponential	Best
Ruggedness	Susceptible to vibration	Not affected by shock	More rugged

Carbon dioxide (CO_2) and methane gas are well-known greenhouse gases. The three classes of CO_2 sensors are the nondispersive infrared (NDIR) sensors, chemical CO_2 sensors and estimated CO_2 sensors. Chemical CO_2 sensors consume low energy but they have short and long drift effects as well as a low overall lifetime. Nondispersive infrared (NDIR) CO_2 sensor is the most common type of sensor used to measure CO_2. They deliver accuracy and fast response time [11]. They do not make contact with the gas and are thus more reliable. Chemical sensors are not as reliable as they can interact with multiple gases and wear from interaction with the gas [11].

The various classes of methane gas sensors are Flame Ionized Detectors (FIDs), catalytic sensors, semiconductor sensors, electrochemical sensors and infrared sensors. Flame ionized detectors are not suitable for some applications as they require the presence of a hydrogen source, an open flame and a clean air supply. Catalytic sensors require the presence of oxygen to operate and are susceptible to poisoning and contamination. Semiconductor types are also prone to contamination whereas electrochemical type requires frequent replacement. Infrared sensors are more robust and long lasting than the other types of sensors. However, they are slightly more expensive.

A computing subsystem
This subsystem is responsible for processing the communication protocols and control of on-board sensors. It consists of the base station that performs these functions. There are two examples of sensing modules that can be used. They include the XBee series 2 chip and MICA 2 module. The XBee module could be used as a wireless module for the node operating on the IEEE 802.12.4 protocol. The MICA 2 module is the more efficient one because of the low power consumption, low cost and high data rate.

A communication subsystem
It includes all the communication protocols for wireless sensor networks. The goal is to support low data rates and low power consumption. General purpose protocols include: Bluetooth, IEEE 802.15.4, and ZigBee whereas Wireless HART and ISA100.11a targets wireless industrial communication protocols [3].Bluetooth is used mainly for exchanging data over short distances.

Wireless HART is mostly used in industrial process automation applications. ISA100.11a was designed to satisfy the industrial requirements such as security, reliability, energy consumption and scalability [12]. ZigBee is a low power, low data rate, low cost wireless communication standard used in home automation and remote control applications [3]. Zigbee module offers a higher bandwidth and range for longer distance application. It also has a longer battery life and a larger network than the other communication protocols.

A power supply subsystem
This subsystem includes a battery source that feeds computing, on-board sensors and communication subsystems. It provides the main source of power for the sensors and other devices that are connected in the node.

IV. CONCLUSIONS
Wireless Sensor Network for environmental monitoring was reviewed and the various subsystems were discussed. Certain environmental conditions for outdoor, indoor and greenhouse were explained. Carbon monoxide gas sensors were reviewed for outdoor conditions. For indoor conditions, sensors for measuring temperature and humidity were discussed while for greenhouse, sensors for measuring methane and carbon dioxide gases were also discussed. These sensors have been compared and the best provided for a given monitoring application. Similarly, the various components for the computing and communication subsystems were also reviewed.

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