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Indoor CO_2 Monitoring using Cognitive Wireless Sensor Networks

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Abstract: As we know, many air buildings are built and the ventilators are not work in timely manner and also less. Indoor air quality become an issue in recent years because it directly relates to human health. Therefore the clean air is essential especially when it comes to indoor air. To mitigate this worriment, the wireless sensor networks (WSNs) have the dormant. Wireless sensor networks are easy to afford and implement. Indoor carbon dioxide measuring is very necessary because at inside environment, its concentration is more than outside environment due to limited space. This paper aims to monitor the carbon dioxide gas through wireless sensors networks. Their causes and impacts on human health are also discussed. The paper represents the benefits of cognitive WSNs over conventional WSNs. It also shows the opportunistic routing protocol used for data routing is helps to transmit data at destination in timely manner and framework for data processing are used to transmit only useful information.

Keywords: Indoor air quality (IAQ), carbon dioxide, Cognitive wireless sensor networks (CWSNs), green house gas, CNOR.

1. INTRODUCTION

IAQ (indoor air quality) relates to the condition of the air inside the buildings as represented by thermal (temperature and relative humidity) conditions and concentration of pollutants that affects the performance and health of occupants. It would be a great work to know the air quality because it directly relates to the health and comfort of building inhabitants. According to the lung association of America, an estimated 40 million individuals have respiratory illness affects and allergies in the U.S. An estimated 7.1 million children under the age of eighteen have these affects .There are number of gases, chemicals and living organisms that can bring air quality down, including dust mites(from carpets, fabric),asbestos, radon, carbon dioxide and mold. Pesticides Cleaning supplies, and other airborne chemicals can also pollute the air. Poor temperature control, inadequate ventilation and too low or too high humidity also impact the quality of air. Tobacco products and deteriorating insulation can be considered pollutants as well as renovation or construction activities make negative effects on air quality.The significant amount of time spend in indoors from most of us, it’s crucial that the air as clean as possible that we breathe. The problems like fatigue, headaches and irritation of the eyes, throat and nose creates by poor IAQ.Some pollutants can cause or deteriorate the indications of allergies, asthma or respiratory illness. Consequently, the development of an accurate system for IAQ monitoring is of great interest [1].

Wireless sensor networks (WSNs) can be quintessential solution to handle this worriment. They consist of inch scale and low cost sensing nodes that can integrate sensing, data processing, packet formation and wireless transmission. Each node has typically several parts: an electronic circuit for interfacing with sensors, a radio transceiver with an internal antenna or with an external antenna, a microcontroller and energy source; an embedded form of power harvesting or normally a battery. With the rapid development of communication technology, remote sensing technology and network technology, there is a necessity that air pollution monitoring system is often designed in wireless form. At present, the GSM, GPRS etc. are wireless mode in air pollution monitoring system. But if we think about installation and maintenance, and complexity, both modes are expensive. On the other hand, WSN have been rapidly developed during recent years. Initially it was for military and industrial controls. Its advantage may include the liability, low cost and simplicity. Due to these advantages, it is now being tested in experimental monitoring issues [16]. Additional benefits include minimizing the need for battery replacements, enlarging coverage of large spatial areas and adding weather proof containers which reduce maintenance. It would allow the monitoring of remote or dangerous environments as well as providing warnings for situations such as earthquakes, floods and inclement weather [2].

2. RELATED WORK

During the last decade, an opportunistic protocols have been developed in many numbers. The first opportunistic routing method is introduced in [3]. In [4,5,6] extremely opportunistic routing (EXOR) protocol, Opportunistic any-path forwarding (OAPF) and MAC- independent opportunistic routing and encoding protocol (MORE) are introduced.

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In [7], a remote carbon dioxide concentration monitoring system is developed. In [8] carbon dioxide monitoring system in an urban area is shown. In [9] real-time indoor air quality monitoring system is proposed. WSNs have application in a variety of fields such as environmental monitoring, indoor climate control, surveillance, structure monitoring, medical diagnostic, disaster management, emergency response, gathering sensing information in inhospitable locations and ambient air monitoring [10,11,12,13].

The device which detects LPG gas leakage as well as fire attack in the home. This device monitor the home with the help of wireless sensors integrated with a microcontroller and a GSM unit. It SMS on mobile and alert the home owners. There is no need to carry any additional equipment because most people already have a mobile phone with them most of the time. By using this structure the security services like police force and fire brigade be informed about the intrusion rapidly and they can take required steps rapidly. The system is safe and cost effective [14].

A proposed system for indoor and outdoor air quality monitoring. The main uniqueness of this paper are the development of an air quality system that uses smart sensors in a wireless network, the embedding of neural network processing blocks distributing the processing charge between the embedded systems and the web browser installed in a personal computer and the development of pc software for sensing node tcp/ip remote control, data storage, advanced data processing and web publishing software related with air quality monitoring system. There are two architectures proposed for wireless communication between a personal laptop and the sensing nodes and that maintains the whole system. Due to limited communication range of hardware used, the systems suitable for indoor applications. Limitation of outdoor range can be overcome using high gain omni directional antenna [15].

We can take the benefit of wireless sensor networks advantages like easy to install, cheap and wireless. In cement factory, the systems which are used only monitors the emissions passing through chimney. Also to monitor the amount of wastes emitted into air mostly, the systems used are CODEL, Magnos27, Uras26, and OPSIS which are all wired systems. Therefore the emissions from other areas are not monitored and also these are more expensive. Therefore some factories fails to install. Due to all these problems, there is a need for employing wireless sensor network [16].

3. CARBON DIOXIDE

Carbon dioxide is colorless, odorless, non-combustible greenhouse-gas that contributes to global warming. It is composed of one carbon and two oxygen atoms and formula is CO2. It is present in the earth's atmosphere at low concentration and acts as a greenhouse gas. In its solid state, it is called dry ice.

Fig 1. Carbon dioxide structure

The multiple natural sources of carbon dioxide in atmosphere are the combustion of organic materials, volcanic outgasing and the respiration processes of living aerobic organisms. The man-made sources of carbon dioxide come mainly from the burning of various fossil fuels (charcoal, coal, petroleum, natural gas) for power generation and transport use. It is also produced by various micro-organisms from cellular respiration and fermentation.

It is the one of the greenhouse gases and, since over the last 200 years its concentration in upper atmosphere has increased from 270 parts per million (ppm) to 350 parts per million (ppm).

3.1. INDOOR CO_2 CAUSES

Earth's atmosphere contains only 0.033 percent of carbon dioxide, but within the home this level can increase, since all humans and animals exhale it as a waste product of respiration. At low levels carbon dioxide is harmless to humans, but when exceed the limit can lead to a range of health problems like headaches, fatigue and breathing difficulties. Some main sources are:

a. Overcrowding: Normally CO_2 levels at outdoors found to be 250 to 350 ppm. Occupied spaces with good air exchange have co2 levels between 350 and 1000 ppm. Since humans exhale carbon dioxide as a part of respiration, overcrowded houses may lead to elevated carbon dioxide levels.

b. Combustion: fossil fuel combustion of wood, coal, oil, charcoal and gas lead to the production of carbon dioxide. The kilogram of coal burnt on a fire can creates 2.86 kilogram per cubic meter of carbon dioxide. Therefore it is important to keep the areas well ventilated where combustion takes place.

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3.2. IMPACTS ON HUMAN HEALTH

Carbon dioxide in its gas form is poison, which cuts off the oxygen supply for breathing, especially in limited areas. Exposure to concentrations of carbon dioxide to 10 percent or more can cause unconsciousness, death or convulsions. Exposure may harm a developing fetus.

Carbon dioxide can cause vision damage, central nervous system injury, elevated blood pressure, abrupt muscle contractions, lung congestion, hyperventilation and shortness of breath. Excess carbon dioxide can also cause dizziness, fatigue, sweating, numbness, headache and memory loss, nausea, tingling of extremities, vomiting, depression, confusion, skin and eye burns and ringing in the ears.

A person more affected by exposure to carbon dioxide if he have a cardiac, lung or blood disease.

4. COGNITIVE WIRELESS SENSOR NETWORKS

Recently, cognitive technology has been used in wireless networks to avoid the limitations imposed by wireless sensor networks. When we integrate cognitive radio with wireless sensors, then it is called cognitive wireless sensor networks. The cognitive technique is the process of knowing through planning, perception, acting, reasoning and continuously updating and upgrading with history learning. Cognitive radio is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This raise the use of available radio-frequency (RF) spectrum while minimizing interference to other users.

There are main two types of cognitive radio, full cognitive radio and spectrum-sensing cognitive radio. Full cognitive radio takes into account all parameters that a wireless node or network can be aware of. Spectrum –sensing cognitive radio detects the possible channels in the radio frequency spectrum. A WSN comprised of sensor nodes equipped with cognitive radio may benefit from the potential advantages of the salient features of dynamic spectrum access such as:

a. Opportunistic channel usage for bursty traffic: Upon the detection of an event in WSN, sensor nodes generate a traffic of packet bursts. At the same time, in densely deployed sensor networks, a large number of nodes within the event area try to acquire the channel. This increases probability of collisions, and hence, decreases the overall communication reliability due to packet losses leading to excessive power consumption and packet delay. Here, sensor nodes with cognitive radio capability may opportunistically access to multiple alternative channels to alleviate these potential challenges.

b. Using adaptability to reduce power consumption: Time varying nature of wireless channel causes energy consumption due to packet losses and retransmissions. Cognitive radio capable sensor nodes may be able to change their operating parameters to adapt to channel conditions. This capability can be used to increase transmission efficiency, and hence, help reduce power used for transmission and reception.

c. Dynamic spectrum access: In general, the existing WSN deployments assume fixed spectrum allocation. However, WSN must either be worked in unlicensed bands, or a spectrum hire for a licensed band must be obtained. Generally, high costs are associated with a spectrum lease, which would, in turn, amplify the overall cost of deployment. This is also contradictory with the main design principles of WSN. On the other hand, unlicensed bands are also used by other devices such as IEEE802.11 wireless local area network (WLAN) hotspots, PDAs and Bluetooth devices. Therefore, sensor networks experience crowded spectrum problem. Hence, in order to maximize the network performance and be able to co-operate efficiently with other types of users, opportunistic spectrum access schemes must be utilized in WSN as well [17].

5. ROUTING PROTOCOL

Designing a routing protocol for wireless sensor network is a difficult task as compare to traditional networks. There is a strict energy saving increasing network lifetime requirement in the case of WSN. The main function of the routing is route selection and data forwarding. The packet forwarding in the traditional routing approaches for multi hop wireless networks is done by selecting the node proactively at the sender side before transmission. Traditional multi-hop routing strategies suppresses the broadcasting nature of the wireless networks by using the Automatic Repeat Request [ARQ] or Forward Error Control [FEC] Data link techniques.

5.1 OPPORTUNISTIC ROUTING

The key idea behind opportunistic routing is to use the broadcasting nature of wireless network such that transmission from one node can be overheard by multiple nodes. Instead of choosing the next forwarder node ahead of time, the opportunistic protocol chooses the next node dynamically at the time of transmission. The forwarding is done by the node closest to the destination.

GeRaF Geographic Random Forwarding (GeRaF), which is based on geographic routing. In wireless network the relay node is not known by the sender but is decided after the transmission. It uses the telecasting nature of the wireless network. Since the topologies are randomly changed, the sender node does not know which of its neighbouring node will act as a relay node.

SAOR simple opportunistic adaptive routing (SAOR) is designed as an improvement to the ExOR protocol. SOAR support multiple flows. The candidate forwarders are constrained to be along or near the shortest path from source to destination. A significant difference between ExOR and SOAR is that SOAR performs the routing decision process on a per-packet basis rather than on an entire batch. Finally, in SOAR the forwarder list is bounded to 5 relays. SOAR incurs slightly less overhead than ExOR and restricts flows as close to the shortest path from source to destination as possible.

ExOR extremely opportunistic routing protocol (ExOR) uses the ETX to select a aspirant forwarder set. It can provide better performances over existing routing protocols. But there are still some problems in ExOR. After a transmission, all candidates with lower priority have to wait for the forwarding of the candidate with higher priority in order. It is not an efficient way to do the spatial reuse [18].

CNOR The cognitive networking with opportunistic routing (CNOR) protocol for scalable WSN's, tries to combine the advantages of opportunistic routing and opportunistic spectrum access (traditional cognitive radio). It is a reactive routing protocol since it discovers routes only when desired. An explicit route discovery process takes place only when it is needed. In CNOR, that process is destination-initiated. The destination node of the network begins the route discovery process and this process ends when a routing path has been established while a maintenance procedure preserves it until the path is no longer available or desired.

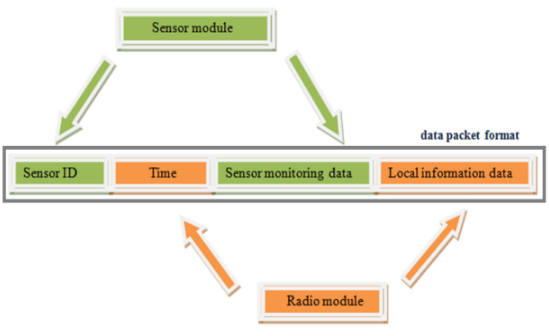
As the network scalability is increased, CNOR tends to discover more paths leading to the increase of the network performance. In CNOR, multiple paths between the source and the destination are maintained. Packets can follow any of those paths, according to the dynamically changing network conditions, such as interference, channel and relay node availability. As the scalability of the network is increased, the number of the relay nodes also increases. Then, CNOR tries to discover more efficient paths towards the destination and increase the total network performance. Moreover, due to the probabilistic choice of the relay nodes, the protocol is able to evaluate different routing paths continuously and choose them according to the condition in every time slot [19][20].

6. INFORMATION PROCESSING

Sometimes collected data might be corrupted due to unreliable readings. Before the data transmission, the initial processing takes place at the radio module. After processing, the module transmits only the important information to the destination. The system minimizes useless data transmissions, minimizing the traffic and energy consumption. The information processing can be done by following ways:

a. Data smoothing, calibration and noise reduction: To save money and energy the sensors we used gives unreliable readings. By using accurate mobile sensor we can reduce sensor noise. The mobile nodes moves between the rooms once every hour and helps in the calibration of the nodes. To remove and identify outliers from the collected data, a smoothing algorithm can be used. If random spike occurs, with the help of smoothing algorithm the node ignores the data and does not transmit it.

b. Packet formation process: Data packet formation and processing takes place at every monitoring board. A packet consist of:-SENSOR IDENTIFIER: the identifier comes from sensor module with its product number. The identifier stores the number of the transmitter that sends the packet and helps the receiver to identify origin of packet. TIME: this field stores exact time when packet was created and time comes from radio module. SENSOR MONITORING DATA: the data passed from the sensor to the radio module. This field stores all the crucial information related with CO2 concentration. LOCAL INFORMATION DATA: it shows the remaining power level of unit and average received signal strength (RSSI) for location information maintenance. Figure 2 (a) shows the packet format and from which module each piece of information comes. The data processing transmission and reception is shown in fig.2 (b).



(a) data packet format

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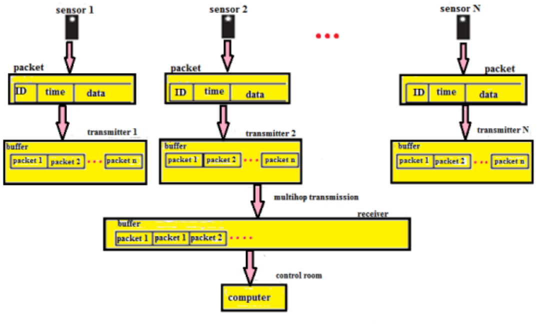

(b) packet process and transmission/reception

Fig2 (a) data packet format (b) packet process and transmission/reception

d. Data processing and storage: when packet reaches the destination, the packet is decomposed to different parts (sensor ID, time, data)[21].

7. CONCLUSION AND FUTURE WORK

A lot of research has been conducted to measure the indoor gases. In this paper, a review on indoor carbon dioxide monitoring through wireless sensor networks has been discussed. The properties of cognitive radio combined with wireless sensor networks to improve the performance of nodes. The overview of routing protocols which followed opportunistic principles and framework for data processing to reduce noise etc. has been discussed. Moreover, there are also need of measure other indoor pollutants like humidity, CO etc. In future, the delay can be removed by using enhanced routing protocol.

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