Review on WSN Based Outdoor Air Pollution Monitoring System

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ABSTRACT: Air Pollution exists as critical environmental issue for every country and countrymen; globally it impacts on the economy, ecosystem, and cultural heritage. To prevent unpleasant changes in Air Quality as well as monitoring of air pollution is crucially necessary. This type of monitoring is possible using Wireless Sensor Network Systems. The amount of six common Air Pollutant CO, O3, SO2, VOC, PM (Particulate Materials), NO2, CO2 etc. able to sense by the WSN system from targeted area monitoring. This paper attempts to provide a review of such outdoor deployed networked systems which dedicatedly designed and to present a new solution to future Wireless Networks for effective implementation and better performance.

KEYWORDS: Wireless Sensor Network (WSN), Outdoor Air Pollution Monitoring, Routing Algorithm, Network Simulation

1. INTRODUCTION

Outdoor Air Pollution is heading as a severe environmental problem for globe due to continuous developments in an industrial scenario and enriched urbanization for a better civilization. As a reflection of this problem humankind suffering from a cardiovascular infection as well as air pollution also make irreversible and profound changes natural resources [1]. And it also leads to acidification, eutrophication of aquatic bodies [1-2]. With the basis of these issues more researchers focusing on air quality monitoring using latest technologies.

Wireless Sensor Networks [3] are grooming technology successfully applicable to monitoring Air Quality, Habitat, Water Quality, Volcano eruption, forest fires, landslides, biodiversity etc [3].

This presented work attempts to discuss Air pollution [1] monitoring using wireless

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network system, conventional systems are classified on the basis of their data transmission path, deployed environment and working style such as Automatic-Non-automatic, Wired-Wireless, Indoor-Outdoor system [3,4,9,20]. As an average person spends approx. 90% time of whole day indoor environment thus indoor air quality is essential to monitor as well as at outdoor environmental pollution will affect entire ecosystem along including human being [4]. Therefore, this work attempts to review specifically an outdoor air pollution and air quality monitoring WSN system to provide a new perspective for future development in WSN based system for their optimized heuristic implementation and development.

2. BASICS OF WIRELESS SENSOR NETWORKS

Wireless sensor networks are made of by a collection of small electronic based devices named as Sensor Nodes or Motes, which are able to aggregate information from targeted area by transducers and it, transmit aggregated information to Sink Node using Wireless communication with appropriate Routing technique. After information processing and handling, data is stored to database system or Server to use it for further preventive, decisive actions and analysis. Basically, Wireless Sensor Network consists of four constructive subsystems Sensor Nodes, Router, Sink Node or Gateway, Information Management-Processing Unit (IMPU) [3-5,9].

2.1 Sensor nodes/Mote

Sensor Nodes are electronic based low cost, compact size and low power consuming devices, formed by using Sensor-Transducers, Microcontroller, Wireless Network Module, power supply, etc. [3-9].
(a) Sensor-Transducers- It is interfaced with the controller to sense and provide the desired parameter as information to Node. It comprises signal conditioning unit to provide a controlled parameter to the controller.
(b) Microcontroller system- The controller is the heart of WSN node; it is employed for data sensing-collecting from sensor-transducer and to process on it for relaying over the network. During selection of microcontroller designer also analysis it's low power, size, cost, processing speed capability, low cost, compatibility, development support.
(c) Wireless communication Module- this is the backbone of the network, it provides data transmission over network wirelessly using a different communication protocol such as wi-fi, ZigBee, Bluetooth.

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(d) Power supply- Complete Network is dependent on this unit, nodes are powered by the power supply to work autonomously, this may using batteries, PV panels, energy converter, and regulators.

2.2 The router

It performs two operations such as sensor mote and in mesh or hybrid topology network, it routes the signals to the gateway. It's having many routing protocols is flat routing, Hierarchical-routing, Location-based routing. In this module over all system same as sensor node or mote such as microcontroller, sensors or transducer, and ZigBee. ZigBee is programmed for as a router operation according to routing protocols. It is also used for real time multi-hop communication, and those routing protocols uses depends on geographic situations also [23].

2.3 The Sink Node

This is more powerful and specially designed node which is used for different functions such as organizing and controlling of the network, aggregation of information from distributed Nodes and information evaluation of gathered from multiple nodes to avoid overhearing and to reject the repetitive form of information. This one is the communicator between the sensor node and server database system, comprise a High-end microcontroller, power supply, wireless protocol module to communicate with IMPU as well as sensor node, memory module to store information provided by sensor node [3-10].

The following elements comprise for Sink Node,

(a) Wireless internal- external system- This communication system are used to form wireless communication between Sink – Sensor node and Sink – server / IMPU.
(b) High- end microcontroller- This unit of sink node system plays the role of the main handling, controlling, scheduling, processing unit, as well as it, utilized for storing information obtained from the multiple nodes.
(c) Power supply unit.

2.4 The Information Management Processing Unit (IMPU)

It is employed for the database, in which all information gathered from different distributed sensor node is stored and processed to presentable form. Origin of information, time, date, node ID and prediction of near future affecting area are indicated by some
IMPU. For managing, handling, presenting and scheduling of data is done by specifically designed software, application, and websites to end user accession. Basically user interface in system designed using computer programming languages such as Visual Basic, HTML, Advance JAVA and other some extra high-end development tools e.g. Android Studio for Smartphone Application [15], data presented to user is provided by Server database system which may situate at local or at remote place and server can be PC, Laptop etc [3-10].

3. ISSUES AND CHALLENGES

Following are the major challenges for WSN which effects on design capabilities and performance of the network for various applications [3-5, 7-9].

a. Hardware for WSN – Hardware in WSN comprises a controller, data converters, sensors, memory, wireless communication modules therefore to build an efficient network, one can have a high range of communication, inexpensive Flash Memory support, minimum energy consumption of Sensor and sensor Node [8].

b. Operating System for WSN – This is the software framework for WSN which employs memory management, peripheral management, and scheduling. To achieve better utilization of hardware through Operating system, it should provide real-time processing concurrency, hardware independence, Multi-hop routing support and low level of programming paradigm [8].

c. Wireless Communication Module Characteristics – Actual working and performance of WSN directly depend on the type of wireless communication module and its characteristic. To achieve the quality of service by the sensor network, modules should consist of further aspects such as error detection subsystem, minimum energy consumption, large range of transmission, adoption of multi-hop networking, distributive sensing and predictable working [6-7].

d. Medium Access Control Schemes – This protocol helps to WSN for regulating energy consumption and to enhance the lifetime of the entire network. MAC schemes should consist regulating aspects such as better switching mechanism, Collision avoidance scheme (occurred due to interference, overcommitting and overhearing), better Scalability, better adaptability, minimum latency with maximum throughput, the inclusion of message passing and provision for real-time requirement [8].
e. **Deployment of node** – Deployment stage is employed for the actual installation of nodes-network in the real world, this task is difficult, unwieldy and slow. Due to Various issues in a task which need to be taken care are to avoid low data yield, disability in self-configuration, concurrent transmission and data loss [3,6,8,11,18,22].

f. *Synchronization in Network* – Objective behind synchronization in networks is to provide a common time scale for all deployed nodes. This service also facing some challenges such as routing, primary path failure in the multipath protocol, less fault tolerance, and data traffic [5, 8].

g. *Calibration of Sensors* - sometimes selected sensor sense required data but obtained values are quite different from actual value, in such case sensor calibration takes place. It is a process of the scaling sensor to obtain corrected value by comparing with standard values. Different issues are present in the calibration of a sensor which is a tremendous number of sensors, limited field of the individual sensor, variation in calibration as per application, aging of sensors and random errors [8, 14].

h. **Network Layer** – As sensor networks are building for a specific application, therefore, routing of the network become focusing aspect on achieving data transmission between sensor node to base station. Routing of the network also facing challenging issues including energy inefficiency, primary path failure in multi-path routing, path repair-replacement, data management and data traffic [8].

i. **Transport Layer** – Reliability in start to end point communication provided by transport layer though no. of designing issues is present such as randomly ordered transmission of fragmented segments, limited bandwidth, bit error rate and packet loss, bad communication performance between neighboring nodes, insensitive to message loss [8].

j. **Data Aggregation-Dissemination** – This process of data collection from distributed multiple sensor nodes and relaying estimated–desired data towards the base station. And data dissemination is defined as the process of the routing of data and queries throughout the network. This also suffers from some design issues as redundancy, distributed sensor networks, power consumption and end-end delay [4, 6-9].

k. **Network Architecture** - Architecture able to define as a set of rules-regulation, protocols, hardware and hardware interfaces to implement specific functionality. Architecture facing with key issues such as discontinues encoding of data, dynamic changes, inflexibility, imprecise control, direct coupling and data path speed [4-9].

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l. Database Centric and Querying – Database and querying in the network is addressed issues such as an interruption in data transmission, interference of signals, continuously and production of data and limited storage [8].

m. Programming Abstraction Model for Sensor Networks - programming model faces issues for sensor networks detailed as general purpose computation, storage capabilities, runtime errors and complexity [8].

n. Middleware for WSN - A middleware for WSN comprises the development of the network, maintenance of network, deployment and execution of application specific sensing. Different issues in designing of a WSN based middleware are such as an interface to the different type of hardware, provision for real-time service, transparency, mobility, scalability, security and dynamics organization [6-8].

o. QoS (Quality of Service) - Quality of service is optimization of the sensor to acquire desired data from distributed sensor node and sending to gateway and base station of application. The quality of service can improve by conquering such issues related QoS like imprecise data-routing, bandwidth limitation, traffic, complex task, buffer size and delay variations [8].

p. Network Security – Network security is more important to achieve better performance and accurate and continuous information through communication. There are basic requirements as per security concern to which are essential to WSN like Confidentiality, Authentication techniques, integrity, secure management, and lightweight encryption [8].

4. EXISTING AIR POLLUTION MONITORING SYSTEM

4.1 Design of air pollution monitoring system using ZigBee networks for ubiquitous-city

In 2007 [10], Jong-Won Kwong and Yong-Man Park et.al presents the design of air pollution monitoring system using the Zig-Bee network for U-city. This proposed work development model comprises sensor node with sensors for Particulate matters (PPD4NS), temperature- relative humidity sensor (SHT71), the CO₂ sensor (CE32-A01). The architecture of system was built using ARM7 (AT91SAM7s64) and event driven Tiny OS, TOSSIM simulator for analyzing different routing protocols. Three routing protocols were selected for simulation test including Gossiping, flooding, modified LEACH, after simulating modified LEACH is finalized for implementation. Sensors and Wireless
communication modules were tested to check transmission range and data collection properties for the network.

4.2 Air pollution monitoring system based on geo-sensor network

In 2008 [11], Young Jin Jung and Yang Koo Lee et.al implemented air pollution monitoring system based on geo-sensor network by installing 10 routers, 24 sensors to gather environmental information such as altitude, illumination, wind direction, wind speed, ultraviolet light, air pressure, temperature, humidity, CO₂, and dust. The system provides alarm and safety guidelines for different remote place condition also with context model for air pollution prevention, data abstraction, and flexible sampling interval to achieve a better battery life of nodes. The information reported on sensor ML.

4.3 A wireless sensor network air pollution monitoring system

In 2010 [12], Kavi Khedo and R. Perseedoss et.al proposed a wireless sensor network air pollution monitoring system for Mauritius. WAPMS implemented advanced data aggregation algorithm called (RCQ) Recursive Converging Quartiles, useful to the merging of data, filter out duplications, and elimination of invalid readings. And system adopted hierarchical routing protocol to obtain desirable power management. Sensor array comprises sensors to gather the amount of described gases such as fine O₃, fine PM, NO₂, CO₂, SO₂, SOₓ from the targeted field which partitioned in 6 small areas. Simulation for WAPMS performed in Jist/Swans simulator which is similar to NS2, GloMoSim in capabilities. The system used DSR protocol which allows the self-organization, the self-configuration for multi-hop network architecture. DSR consists two phases Route discover, Route maintenance.

4.4 A mobile GPRS- sensor array for air pollution monitoring

In 2010 [13], A. R. Al-Ali and I. Zulkernan et.al presents and tested system for air pollution monitoring using GPRS-Sensors array The system comprises microcontroller based mobile data acquisition unit, internet enabled air pollution server, a gas sensor array for level detection of CO,SO₂,NO₂ as well as GPRS and GPS modules. DAQ collects level of air pollutant and packs in the frame including time, date, location and uploads to the server system with the help of GPS, GPRS, and public mobile network. The air pollution server is in the interface to Google Maps for indication of real time collected pollutant
level in the Sharjah city, UAE. The developed system can be deployed on mobile public transport system to collect and upload a level of air pollutant for the end user.

4.5 Real time air pollution monitoring system

In 2011 [14], Raja Vara Prasad et.al presents real-time air pollution monitoring system, to monitor gases amount of CO2, NO2,CO, O2 using commercially pre-calibrated and manually calibrated sensors such as TGS4161(CO2 ), KE2(oxygen) and with temperature and relative humidity. Expensive Libelium WASP, sensor board were employed as sensor mode which supported with lightweight middleware and web graphical user interface, test bed system's five nodes/motes deployed at the campus of IITH. Issues regarding implemented system were studied in presented work.

4.6 Participatory air pollution monitoring using smart phones

In 2012 [15], David Hasenfratz and Olga Saukh et.al describes implementation of participatory air pollution monitoring using android based smart phone to acquire information about ozone concentration, temperature and relative humidity, architecture consist of embedded system, ZigBee module and gas sensor MiCS-OZ-47 and RS 232, USB-RS232 translator and Cynogen Mod Custom kernel. HTC Hero android phone used to collect participatory air pollution data.

4.7 WSN based air pollution monitoring system

In 2013 [16], Amol Kasar and Dnyadeo Khemnar et.al designed and developed WSN based air pollution monitoring system, which consists of the zig-bee network for wireless parameter transmission, integrated Atmega16 based sensor board to monitor CO2,NO2,SO2 with UART, op-amp based signal conditioning circuit and database server. Hardware building blocks in designed system were an atmega16 controller, Zigbee module, an array of MG81, MQ135, MQ6 sensor and RS 232 for serial communication. It also provides AQI report in different colors.

4.8 Wireless sensor network for real-time air pollution monitoring

In 2013 [17], Elias Yaacoub and Abdullah Kadri et.al describes real-time ambient air quality monitoring system. This comprises and developed by using distributed air
pollution monitoring MGMS stations which are able to communicate wirelessly with backend QMIC developed pollution server, every MGMS static sensor node was built using gas sensors array to sense CO, O₃, NO₂, H₂S, SO₂, NO and meteorological sensors for sensing temperature, relative humidity powered with solar panel, with in addition to data acquisition as well as wireless communication. Total 4 number of static sensor nodes (Qatar1-Qatar4) deployed to cover an area of 1 km². Air pollution server aggregate information about real-time ambient air pollution using 4 MGMS static node and uploaded and delivered to end-users through website and mobile application.

4.9 ASWP: A long-term WSN deployment for environmental monitoring

In 2013[18], Miguel Navarro and Tyler Davis et.al presents ASWP: a long-term WSN deployment for environmental monitoring, which integrates initial 42 sensor nodes of MICAz, TinyOS-based platform, XMesh routing software and MDA-300 acquisition board with periodic sampling provision as well as using a multi-hop routing protocol. The system worked on data packet duplication issue, data packet loss and network maintenance. The presented system has been deployed at Pennsylvania, the USA in an outdoor forest environment.

4.10 Pollution monitoring system using wireless sensor network in Visakhapatnam

In 2013 [19], P. Vijnatha Raju and R.V. Arvind et.al presents pollution monitoring system using wireless sensor network for Visakhapatnam, designed and simulated system for concentration collection of three air pollutant like CO, CO₂, SO₂. The system built using Atmega328p controller's Arduino development board along with ZigBee transceiver module, ZigBee coordinator modem with X-CTU software and manually tested sensor like. The program flow suggests effective consumption of energy source and sensors were interfaced through op-amp based signal conditioning circuit to provide a desirable output voltage to the controller from the sensor.

4.11 Air pollution monitoring system based on wireless sensor network- simulation

In 2014 [20], Vasim Ustad and A. S. Mali et.al introduces and simulates an air pollution monitoring system based on the wireless sensor network, to monitor concentration level of air pollutant in the environment due to the industrial process. The proposed system collects information about pollutant CO, SO₂, and dust concentration, the hardware
architecture of system consists of the sensor array (CO, SO2 and dust), PIC16F887 Microcontroller with a serial communication port and inbuilt ADC, ZigBee End modems, ZigBee coordinator modem, GSM modem, PC as a database server with internet accessibility. Presented work simulated in Proteus circuit simulator and MicroC Pro for PIC controller concurrently data sent to database server to an indication to end user on live environmental monitoring faceplate.

4.12 Zigbee based wireless air pollution monitoring system using low cost and energy efficient sensors

In 2014 [21], G. Swagarya and S. Kaijage et.al implement ZigBee based wireless air pollution monitoring system with low cost and energy efficient sensors, system consists integrated mobile DAQ with PIC 16F877 microcontroller, sensor array (MQ family-131,135,136), GPS module, high-end PC as pollution server, Zigbee modem. Sensor array aggregate information about concentration level of CO, SO2, and NO2 through op-amp based signal conditioning for the microcontroller. Software architecture design of system engaged in different functions such acquiring real-time information, physical location, time-date of pollutants, encapsulation of data, transmission of data to pollution database server which interfaced with Google MAP to provide 24x7 information presentation. The user interface for this system presented using advanced Visual Basic application and also on 16x2 LCD display.

4.13 Sensor deployment for air pollution monitoring using public transportation system

In 2015 [22], James et al. developed air pollution monitoring using public transportation system for Hong Kong, to perform simulation of system sensor nodes were deployed on the city buses and implemented Chemical Reaction Optimization (CRO) to achieve better optimization by using formulated BSDP (bus sensor deployment problem) in this evaluated coverage percentage, total number of sensor, data accuracy and performance. Also compared obtain values of 'c' with CRO, SGA and SRM to decide which meta-heuristics was better to solve BSDP.

5. COMPARATIVE REVIEW CHART OF VARIOUS OUTDOOR SYSTEMS
## Table 1. Comparative study of various outdoor systems

<table>
<thead>
<tr>
<th>Available System Reference</th>
<th>No. of Nodes</th>
<th>Environmental Sensor in Sensor Array</th>
<th>Cost of single node</th>
<th>Power consumption</th>
<th>Protocol of Nodes</th>
<th>Data transmission Protocol to Server</th>
<th>Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jong-Won Kwon et. al [10]</td>
<td>5</td>
<td>Particulate matters, temperature- relative humidity, CO₂</td>
<td>High</td>
<td>Medium</td>
<td>ZigBee</td>
<td>NA</td>
<td>(PPD4NS), sensor (SHT71), CO₂ sensor (CE32-A01) ARM7 (AT91SAM7s64), ZigBee</td>
</tr>
<tr>
<td>Raja Vara Prasad Y et. al [14]</td>
<td>5</td>
<td>CO₂, NO₂, CO₂</td>
<td>High</td>
<td>High</td>
<td>IEEE802 .15.4</td>
<td>TCP/IP</td>
<td>Libelium WASP, Sensor board</td>
</tr>
<tr>
<td>David Hasenfratz et. al [15]</td>
<td>1</td>
<td>ozone, temperature, relative humidity</td>
<td>low</td>
<td>low</td>
<td>ZigBee</td>
<td>TCP/IP</td>
<td>ZigBee, MiCS-OZ-47, RS 232, USB-RS232 translator, HTC Hero</td>
</tr>
<tr>
<td>Amol R. Kasar et. al [16]</td>
<td>2</td>
<td>CO₂, NO₂, SO₂</td>
<td>Low</td>
<td>Medium</td>
<td>ZigBee</td>
<td>NA</td>
<td>Atmega16, ZigBee, MG81, M135, MQ6, RS 232</td>
</tr>
<tr>
<td>A. Kadri et. al [17]</td>
<td>4</td>
<td>CO₂, O₂, NO₂, H₂S, SO₂, NO₃</td>
<td>High</td>
<td>Low</td>
<td>NA</td>
<td>TCP-GPRS</td>
<td>Atmega2560, GPRS, Sensor array</td>
</tr>
<tr>
<td>M. Navarro et. al [18]</td>
<td>42</td>
<td>Temperature, humidity</td>
<td>Medium</td>
<td>Medium</td>
<td>IEEE802 .15.4</td>
<td>TCP/IP</td>
<td>Crossbow MICAz, Mote IV Tmote Sky, MDA300 DAQ</td>
</tr>
<tr>
<td>P. Vijnatha Raju et. al [19]</td>
<td>NA</td>
<td>CO₂, CO₂, SO₂</td>
<td>Medium</td>
<td>Low</td>
<td>ZigBee</td>
<td>NA</td>
<td>Atmega328p arduino, ZigBee transceiver, Op-amp</td>
</tr>
<tr>
<td>G. Swagarya et. al [21]</td>
<td>NA</td>
<td>CO₂, SO₂, NO₂</td>
<td>Low</td>
<td>Medium</td>
<td>NA</td>
<td>TCP over GPRS</td>
<td>PIC16F877, GPS, DAQ, Sensor, Op-amp</td>
</tr>
</tbody>
</table>

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6. CONCLUSION

This piece of work targets on progressive and advancing wireless sensor network technology for application of outdoor air pollution monitoring system, a wide range of work available in outdoor air pollution quality monitoring is available with various issues in existing WSN based System. This paper provides a closer look at basics and challenges front of WSN. Comparative study intended to help for aspiring research work with a better selection of modules to conquer issues regarding design, development, performance and efficiency of the outdoor air pollution monitoring system.

REFERENCES


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