Smart City and Vehicle Pollution Monitoring Using Wireless Network System

Lateef Adesola Akinyemi[1,2], Tunji Makanjuola[2], Oluwagbemiga Shoewu[2*], Comfort Oluwaseyi Folorunso[3]

[1] Department of Electrical Engineering, University of Cape Town, Cape Town, South Africa
[2] Department of Electronic and Computer Engineering, Lagos State University, Lagos, Nigeria
[3] Department of Systems Engineering, University of Lagos, Lagos, Nigeria

Email Address

lateef.akinyemi@lasu.edu.ng (Lateef Adesola Akinyemi), tunji.makanjuola@lasu.edu.ng (Tunji Makanjuola), oluwagbemiga.shoewu@lasu.edu.ng (Oluwagbemiga Shoewu)
*Correspondence: oluwagbemiga.shoewu@lasu.edu.ng

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Abstract:

Advancements in the field of communications are moving towards the internet of things (IoTs). Wireless Sensor Networks (WSN) can be used to monitor environmental conditions such as pollution using independent sensors communicating with each other using the IoTs technology thereby leading to a more accurate environmental monitoring system. Air pollution is a critical environmental challenge which is a major concern in cities and will have to be reduced if cities are to be regarded as smart cities. It has negative short and long term effects on human health that would deter people from moving to cities which would ultimately prevent economic growth. Therefore, the air pollution around the city and along traffic routes could be monitored using WSN nodes. In this work, the stationary nodes around the city would be deployed periodically to collect pollution data from sensors at the node. These data would be stored locally in its memory with a time and location stamp. Mobile nodes placed on public buses, buildings and vehicles would wirelessly collect the data as they pass by the stationary nodes. The data would then be processed once the nodes arrived back at the pollution monitoring system. In the proposed architecture, the stationary nodes run on ZigBee standard while the mobile nodes run on fifth generation (5G) and Long-time evolution (LTE).

Keywords:

Smart City, WSN, Cloud, Pollution, 5G

1. Introduction

Wireless sensor networks consist of distributed autonomous sensors to monitor environmental conditions which will be pollution in our case [1]. WSNs are in much use due to the fact that they are quite easily affordable, fast and easy deployment, energy efficient, no need to install a central controller, highly scalable. However, it is not as secured as the Wi-Fi-based system and the coverage distance is limited. It is believed that with increased popularity of these WSNs, the prices would drop and become more economical [2]. A typical WSN node is depicted in the block diagram in

Figure 1 with four (4) basic units: sensing, processing and storage, communication and the power. The sensing unit, in this work, monitors the pollution level which is then processed by the microcontroller/microprocessors in the processing unit and then passes the data through the communication network to the main location where it is then analyzed and interpreted. The efficiency of the whole system comes down to how well the system can communicate regarding speed, stability and protocols. Some of the challenges include selecting routing protocols; media access control, power management and coverage.

The nodes need to be constantly updated and maintained to increase their lifetime. A Radio component that can communicate the sink node or router which collects the sensed pollution level from sensor node and forwards to pollution server. They also need to be checked on a regular basis for malfunction as this could affect analysis of the data. The network could be updated regularly to improve on the design and collection of data.

A typical sensor node would consist of the transmitter, receiver, and data storage and power source. Its primary responsibility would be to send its data to the moving node placed on buses and cabs driving on a predetermined route. Possible sensors that could be used to detect air pollution could include smoke concentration, gas and dust particles. Analyses would then be used to determine the extent of the pollution. There has been an increase in deaths due to air pollution because of the presence of volatile organic compounds in the air [2].

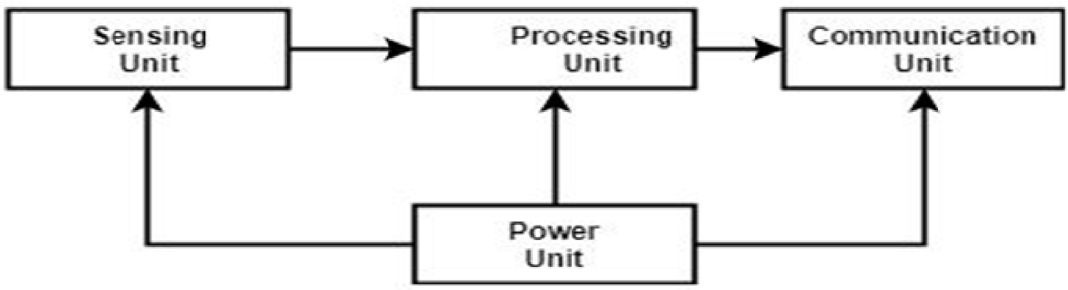

Figure 1. *Block Diagram WSN with four (4) Basic Units.*

The key contributions of this paper are summarized as follows: To propose a smart city and vehicles pollution monitoring system based using Wireless Sensor Network system and setting a threshold for the environmental pollutants that is tolerable ,acceptable and allowable for living creatures.

The rest of this paper is organized as follows: Section II talks about the related work. Section III presents the theory behind the study in terms of the proposed method for pollution detection. Section IV discusses the preliminary results and discussion with explanation on the parameters to be used.

Section IV concludes this paper.

2. Related Work

The amount of people moving from rural to urban areas is increasing and new cities will be needed to accommodate for the influx. The reason for the influx of people is mainly due to no development in the rural areas. There are many challenges for urban living and addressing these challenges in the beginning will pay off in the end and reduce losses. Smart sites also attract investment which increases the overall well-being of the city and its citizens.

A smart city is an urban area that is advanced in terms of infrastructure, service delivery, communications and attractiveness. Information technology acts as the primary infrastructure and the medium for providing services to citizens. Some of the benefits include increased efficiency and new technology adoption which most likely improves the quality of life of its citizens. Economic development and activity would be much more sustainable as these cities would attract young and intelligent professionals [3,4].

This concept came during the economic crisis and coming up with alternative solution was the cost reduction in order to keep municipalities afloat. IBM began working on the smarter cities back in 2008 which was part of its Smarter Planet Initiative. The idea spread like wild fire once companies and countries released its potential. Some of the countries that have researched and started implementation include China, UAE and South Korea. Countries that have already implemented such ideas include Aarhus, Cairo, Verona, Amsterdam and Vienna. The community needs to be actively involved in implementing a smart city in order for it to be a success. This includes energy saving as well as upgrading the infrastructure [4].

In [5], the authors carried out work on the Wireless Sensor Network (WSN) architecture for smart irrigation system. However, the work failed to address the issue of congestion in the network, power consumption and reduction in the number of nodes. The authors in [6] present a new Wireless Sensor Network (WSN) architecture deployment approach for Air pollution. In this work, pollution data were analyzed to minimize the optimal positions of sensors and sinks while reducing the cost of deployment of the nodes but failed to address the power consumption issue by the nodes. More so, in [7], the authors worked on Smart Vehicle Monitoring system for Air pollution detection using WSN. The work carried out by these authors was able to achieve the monitoring of humidity temperature and other environmental factors.

Additionally, in [8], the authors carried out work on a prototype system with statistical data analysis based on Wireless Multi-sensor networks for smart cities. By this, the authors were able to show that inconsistency, missing of data and noisy data could be analyzed and extrapolation based on the measurements in time and space can be achieved. It was equally demonstrated that short-term forecasts and smoothed maps estimation can be achieved via reliable estimates on the data consequently making the database to be represented geometrically. This can help the people for public services that may be needed.

Furthermore, in [9], a smart solutions for smart cities using wireless sensor network for smart dumpster management was done by the authors. In this study, the HC-SR04 ultrasonic sensors were used based on the study. This results into the level sensing results that could be used at the municipal authority or provincial government server to deploy the number of trucks and personnel for the collection of waste. It was suggested that planning and routing can be minimized via the time and conserves fuel consumed by the trucks. Finally, the proposed algorithm was used to enhance and optimize the fuel consumed by the trucks and time.

Besides this, in [10], the authors developed a scheme based on multiple mobile sinks in event-based wireless sensor networks using traffic conditions in smart city applications. In this study, striking results were obtained based on the computationally dynamic sinks movement in reactive sensor networks which supports efficient adaptation to event-based monitoring system in smart cities environment.

2.1. Proposed Method for Pollution Detection

A Sensing unit is designed and programmed to sense gas pollutants in air [1]. Some common examples of properties or parameters that are monitored are light, temperature, humidity, pressure, etc. a converter that transforms the sensed signal from an analog to a digital signal; The Processing Unit in the Microcontroller, process the signals sensed form sensor with help of embedded memory, operating system and associated circuitry. A Radio component that can communicate the sink node or router which collects the sensed pollution gas level from sensor node and forwards to pollution server which is in the administrator office or back office (central office). Powering these components is typically one or two small batteries. There are also wireless sensors utilized in applications that use a fixed value, wired power source and do not use batteries as a power source.

A cluster will consist of various sensors connected directly to a main sink node. Each sensor can communicate directly to the sink node eliminating latency [2]. In this work, the strategically placed clusters (radio components) around the city will be used for data collection and the mobile nodes will collect data along the predetermined routes as previously discussed. There will be indoor units placed within short distance from the street and weatherproof outdoor units placed along the predetermined route. The best option for the mobile nodes would be to place them on the commercial buses or vehicles which move around the smart city. The Figure 2 shows nodes installed on the vehicles [3].

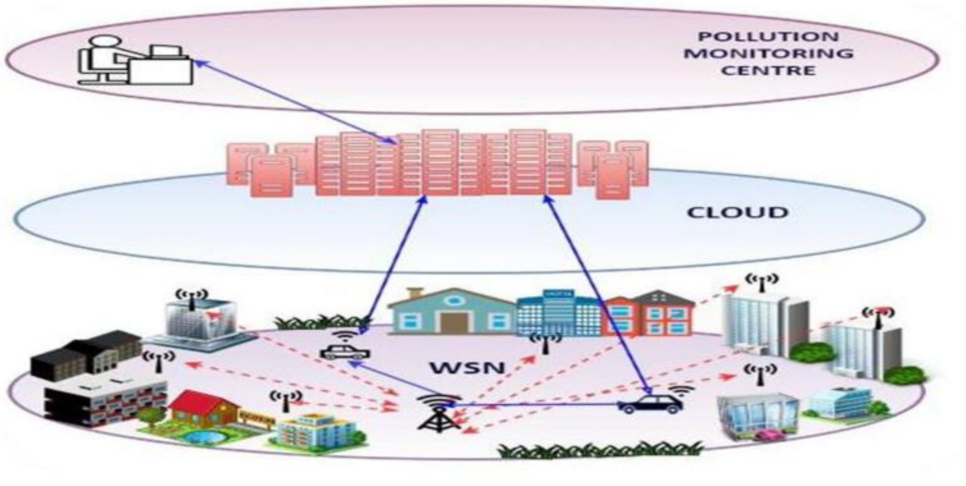

Figure 2. *Vehicles and Smart cities collecting data from the stationary sensors around the city.*

Example of data sample that would be collected could include smoke levels, dust and gas levels. The sink nodes would constantly be looking for mobile loads in the vicinity and establish a connection when one is close by. Once that data samples are analyzed, areas with larger concentrations of pollution can be singled out and measures could be put in place to reduce the pollution. The source of the pollution can be estimated by means of statistical analysis of received data. The overall system would consist of many sub-systems scattered around the city. Each sub-system would have each of the different sensors to measure each pollution type.

2.2. Architecture and Network System

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In this section, the proposed architectural system design between the connection of the vehicles and smart cities to the cloud will be discussed by using Figure 3. The network would make use of LTE/5G systems technology. It has very fast transfer speeds, ideal for long range communication and does not require much power. This technology will be utilized on the vehicles which require a mobile connection. The WSNs positioned at fixed location in the smart city would run on the ZigBee standard. These stationary WSNs would then route the data to the moving vehicles. They will be ZigBee wireless sensors at the fixed locations around the route that transfer data to the moving buses. Once the data are collected by the vehicles, it will be uploaded using LTE/5G to a cloud network where it will be analyzed. The LTE / 5G is a relatively new technology which means it will be compatible with new devices and upgrades coming out in the Figure 3.

Figure 4 below is a flow chart of the wireless sensor network that will be implemented in smart cities. The sensor nodes will collect data from the air and transfer it to the sink node using some communication methods. Once the sink nodes have collected data from all the nearby sensors, they will transmit the data to an online server via the mobile vehicles. The data will be processed as discussed earlier and can be viewed online [3].

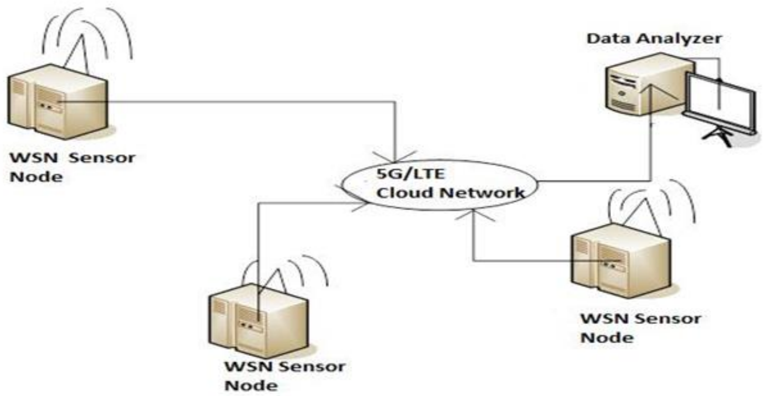

Figure 3. *5G/LTE network connecting the vehicles and smart cities to the cloud.*

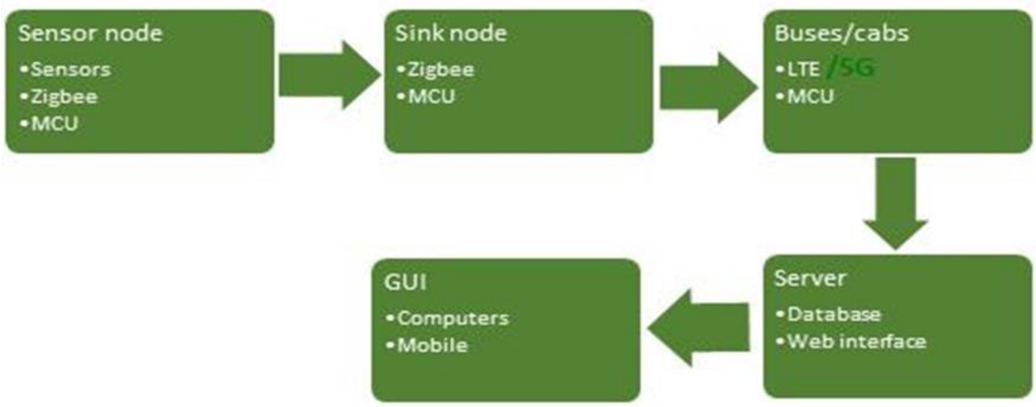

Figure 4. *Adaptive wireless sensor network.*

3. Preliminary Results and Discussion

In this section, the preliminary results will be discussed based on the Table 1 below. The Table 1 shows a different level of threshold that would be set ab initio for various

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monitoring environmental pollutants namely smoke, dust and dust. In this regard, there would be an indicator installed alongside the devices in the building and vehicles that keeps eye on the level of the pollutants in the vehicles and building in the smart city. As soon as it detects that there is a high or extreme level of pollutant, it quickly sends an alert which is connected to pollution monitoring centre via 5G/ LTE where appropriate measures would be taken to control such occurrence. In this the proposed architecture, analyzed data can be viewed ubiquitously in the globe and can have access to the information about the pollution levels and rate through the 5G/ LTE cloud network system. In the full implementation of this proposed work in the nearest future, the pollution dataset of major cities in Nigeria such as Lagos, Kano and Abuja would be used. The common values of simulation parameters that would be employed are depicted in Table 2.

Table 1. *Threshold Level & Ranges for Different Pollutants.*

Pollutant	Middle	High	Extreme
Smoke	3-5	6-7	8-10
Dust	3-5	6-7	8-10
Gas	3-5	6-7	8-10

Table 2. *Simulation Parameters & Values.*

Parameters	Values
Map of resolution discretization	(100-200)m
Number of time instants	(1-10)
Sensors communication range	(50-100)m
Sensor price/cost	1

4. Conclusions

In this paper, we propose a smart city and smart vehicle pollution monitoring system that depends on the data collected and analyzed from the cities and vehicles using some statistical method in order to minimize the pollution in the environment and society. Ultimately, this concept would contribute to the development of a smart city. By the use of 5G/LTE cloud network, a large chunk of data of various and different vehicles, buses and buildings records can be kept and retrieved for future application on how to improve the monitoring system as technology advancement improves. The influx of people from rural areas to cities would increase the pollution proportionally. If it is not contained to acceptable levels, the consequences would be detrimental to the general population as seen in Beijing and other Chinese cities. This concept would isolate areas with high levels of pollution, so that the city can find ways to reduce it to acceptable levels.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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