Study and Evaluation of Wireless Sensor Networks Performance

Luay Abdulwahid Shihab
Assist Prof Nursing College, Basrah University, Basrah, Iraq.
E-mail: Luaay.abdulwahid@uobasrah.edu.iq

Received September 12, 2021; Accepted December 12, 2021
ISSN: 1735-188X
DOI: 10.14704/WEB/V19I1/WEB19172

Abstract

This project analyses vehicle behavior from measurements of air pollutants (CO2) sound pollution levels, measured in ppm and decibels respectively. Such measurements are taken by a wireless sensor network mounted in the Baghdad Dora Express way, Iraq. Four sensor nodes and a coordinator form the wireless network based on the Zig bee norm. The sensor nodes wirelessly send the data to the coordinator, who displays the actions defined by the measurement curves through a graphic interface built in JAVA and store the data on a MySQL web server. The analysis of vehicle behavior considers noise levels and carbon dioxide concentration higher than their base reference value, measured in a certain period of time. Comparative and individual graphs of noise and carbon dioxide concentration taken in two days of measurement, belonging to the nodes, show greater vehicular activity in peak hours that are reduced at the end of the day and at midnight, in addition to the individual performance of the nodes within the network, which depends on the infrastructure of the Integrated Security System ECU911.

Keywords

WSN, Pollution Levels, Zigbee, JAVA, MySQL.

Introduction

Wireless sensor networks have been the subject of study for some time, mainly due to technological innovations introduced by the advance in micro-electro-mechanical systems, wireless communications and digital electronics. The principle of a wireless sensor network is the use of a large number of sensor nodes subject to failure with wireless interconnection between them. Such sensor nodes must be low cost, low consumption and small in size. These restrictions imply a series of requirements for communication protocols never before found on such a scale [Qassim, Alaa & Tarish, Hiba & Sapih, Narjis. (2018)]. Much has been researched but there is still a much greater amount of research to be carried out so that this type of network can really be used.

Currently the sensor elements are part of a wired network, which suffers from the functional stability of a control element that adds value to the product. The elements used in this network are of considerable size, require a complex installation process, and their maintenance often becomes a problematic task during the production season [Van Steen, M., Tanenbaum, A.S. A brief introduction to distributed systems. Computing 98, 967–1009 (2016)].The design of a wireless sensor network involves a number of factors to be considered. Of the most important we have Fault tolerance, Scalability, Production cost, Operating environment, Hardware restrictions, Network topology, Transmission medium and power consumption [Panneer Selvam, Arun Mozhi Devan & Hussin, Fawnizu & Ibrahim, Rosdiazli & Bingi, Kishore & Nagarajapandian, M.. (2019)]. These factors are the most important for the development of algorithms capable of handling these requirements imposed by the network. Of course, this is just one of the possible lists. Much work has been done on some of these topics, but much remains to be done to integrate these factors into a single solution.

Iraq's registered motor vehicle was recorded in Dec 2015 as being 3,900,000 units. This indicates an improvement over the previous registered data on Iraqi motor vehicles remains in CEIC and is documented by the International Motor Vehicle Manufacturers Organization. The CO_2 emissions of Iraq in 2014 were estimated to be 4.812 Metric Tons. According to the WMO [Kadri, Abdullah & Yaacoub, E. & Mushtaha, M. & Abu-Dayya, Adnan. (2013)], the increase in CO_2 shown by the above figures is more than enough reason for Iraq to start working on the climate adaptation of its population due to climate change. Then, it is intended to develop a monitoring system for CO_2 emissions and noise pollution produced by vehicular traffic [Kakouei, Aliakbar. “2012]. First of all, we seek to obtain a portable device that is adaptable to most sectors in the city of Baghdad, Iraq without the need to install large infrastructures [Van Steen, M., Tanenbaum, A.S. A brief introduction to distributed systems. Computing 98, 967–1009 (2016)]. In this way, we can improve by contributing to society to maintain order and monitoring the amount of CO2 that is emitted in the different sectors [Granda, Byron &Belduma, Luis & Gonzalez, Edwin &Sarango, Angel (2017)].

There are a lot of Internet users and even in homes whenever abounded use of the Internet and communications quickly abounded problems [Luaay abdulwahed shihab , (2015)].and are local networks of the various threats to the growing increasingly been used encryption and that the protection is being from entering the local network and the protection of user and tampering with the computer and find out local area networks has become a major tool to many companies and factories[Luaay AbdulWahed Shihab, (2012)].that any information must be correct, accurate, and available to be stored, retrieved, processed, and made available safely and reliably ,[Luay Abdulwahid Shihab , (2020)].

Methodology

In addition, each part and stage of the project will be explained until the design of the wireless network.

1. **Function and block diagrams of the research project:** The operating diagram of the sensor nodes is shown in Figure 1 We use an Arduino nano to collect the data received by the carbon dioxide and sound sensors, as our key feature. The microcontroller processes the data that is subsequently sent to the Xbee modules through serial communication. The Specified segments set up the WSN for the sensor nodes to the sink node or the coordinator node. We also have a real-time clock connexion at the sensor node to warn people about the speed of noise measurement and carbon emissions. The power pack comprises a module for connecting a rechargeable battery of lithium polymers and a solar panel. This device makes the project autonomous, allowing the battery to charge using solar energy resources when the default electricity supply fails or when a power outage occurs.

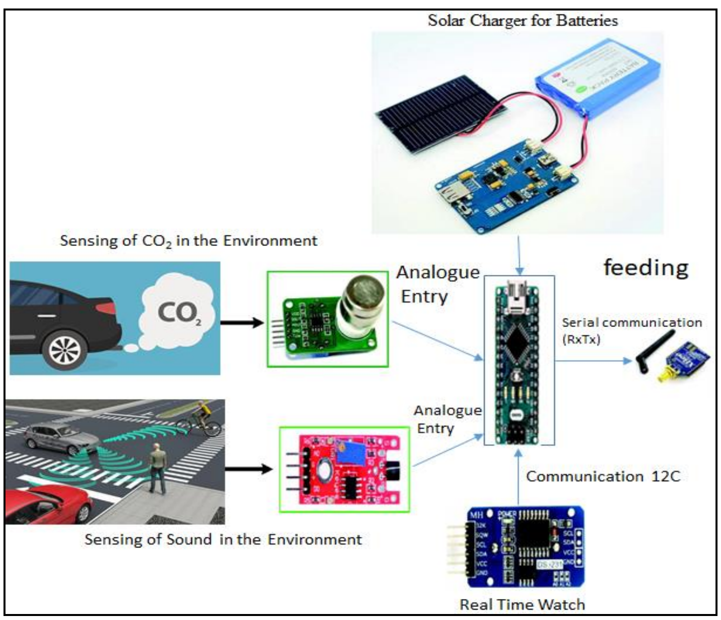

Figure 1 Operation diagram of the sensor nodes belonging to the system

The operational diagram of the node of the coordinator with its fundamental sections is shown in Figure 2 Data from the sensor nodes hitting an Arduino mega module are obtained by the coordinator. The use of this Arduino board was chosen, as it consists of four serial ports, because of many serial communications used in this node. The Raspberry Pi is linked directly to this computer. The app built in Java (NetBeans) is on this minicomputer. The measured data from the nodes are saved and shown in the graphs when the sensor nodes wirelessly transmit. The last point is that the Raspberry pi is connected to a local network via the remote desktop. This choice allows the user to check the network monitoring and to observe the data chart taken from the environment during the day.

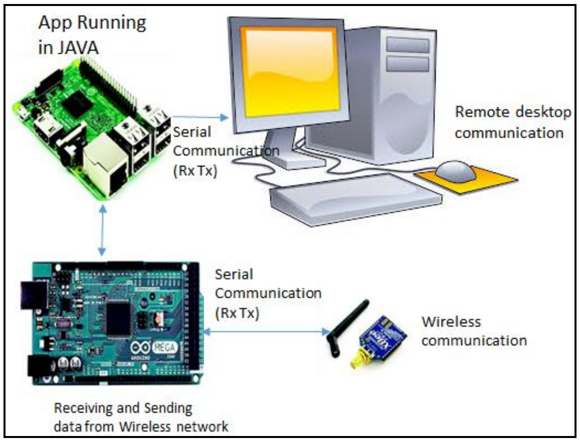

Figure 2 Operation diagram of the coordinator node belonging to the system

The project block diagram in general will be shown in Fig.3. The system consists of two key blocks according to the diagram. The second is the part of the Coordinator node in which our Java application is created. The first refers to the sensor node. The measurements (sound and CO_2) of each node are shown in this application. In later sections of this section, all functions performed by any block are defined in detail.

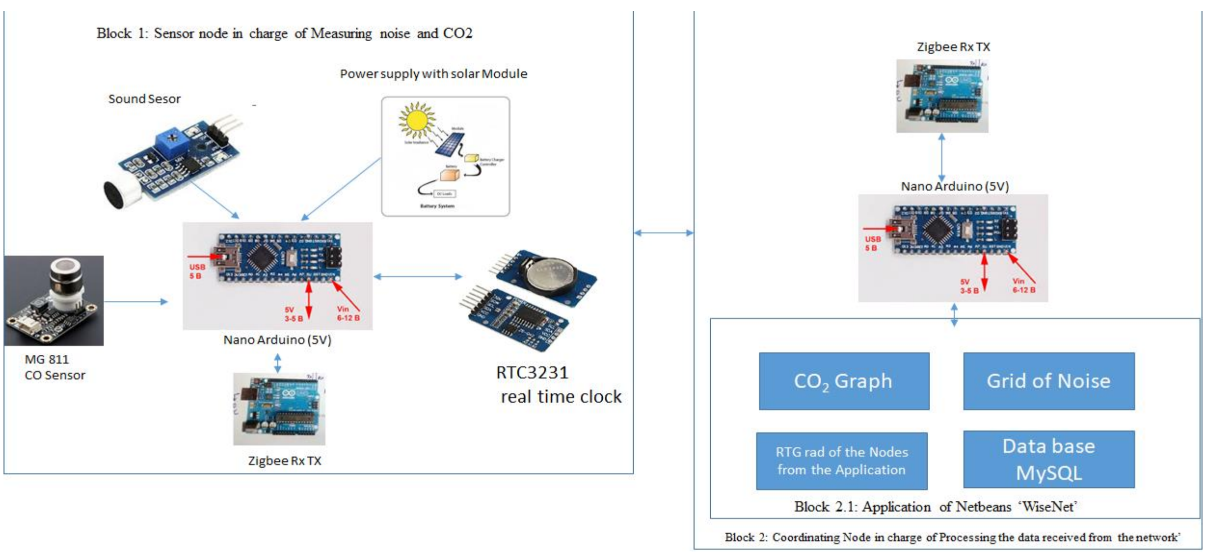

Figure 3 System block diagram

2. **Selection of components for project design**: The choice of electronic components was made according to the requirements of the project to achieve the established objectives. The design of the application was done in free software, in this case in the Java programming language (in the Netbeans programming environment). The choice of devices for the hardware was also made taking into account that they are free to use without any type of licenses. Next, the main characteristics of each of the selected components are MG-811 CO_2 meter sensor module [Patil, Shweta & Deshpande, Pradeep. (2020)] .MG-811 Sensor Specifications similar to the literature [Shen, Chen. (2014)]. Sparkfun sound detector module; Lipo Rider Pro solar power (to work with the energy of the sun since it costs with a power stage through solar panels. This stage also works as a Li-Po or Li-Ion battery charger); DS-3231 real time clock module; Arduino Nano board (the nano can be powered with 5V through a USB-Mini connection or externally through pin 30); XBee-PRO® 900 DigiMesh Module (XBee-PRO® 900 DigiMesh Module Specifications maintained as given ; Raspberry pi 3 B board and Arduino Mega; USB to serial CH340 module.
3. **Design and construction of the housing of the "WiSeNet" project:** First, it should be taken into consideration that two housings will be made. The first for the nodes that will measure the level of noise and CO_2 in the air and the second for the coordinating node. This section will show the design of both that was made in the Free CAD program. The design of the box for the sensor node can be seen in figure 4 and that of the coordinator node in figure 5.

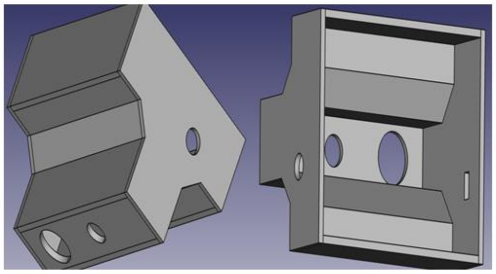

Figure 4: 3D housing design for the sensor node

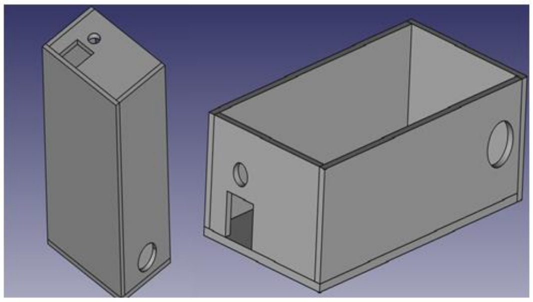

Figure 5 3D shell design for the coordinator node

4. **Functioning of the "WiSeNet":** The MG-811 sensors and the Sound Detector of Sparkfun, monitor for carbon dioxide and sound changes in the atmosphere. It has a real time clock that makes it possible to know the exact time and date of the sensor measurement. All these specifics are handled and adapted by the Arduino Nano. After the coordinator is accommodated it would be possible to quickly classify a header with the corresponding node number. The data are sent to the Xbee sensor node module on a serial basis.

The Xbee modules sensor node is connected on the coordinator, the Xbee is connected on a star-type network and the data frames for each node are given in different areas. The Xbee coordinator will be linked serially to the Arduino Super, which receives data and sends it with an algorithm and then sends it to serial machine Raspberry Pi 3B, and the Java based application will be installed on this minicomputer to view the charts of the collected data. The calculation takes place every ten minutes. In addition, all node clocks should be reset to maintain network synchrony. The graphs obtained following the above method are shown in Figure 6. These graphs were taken while checking for network validity.

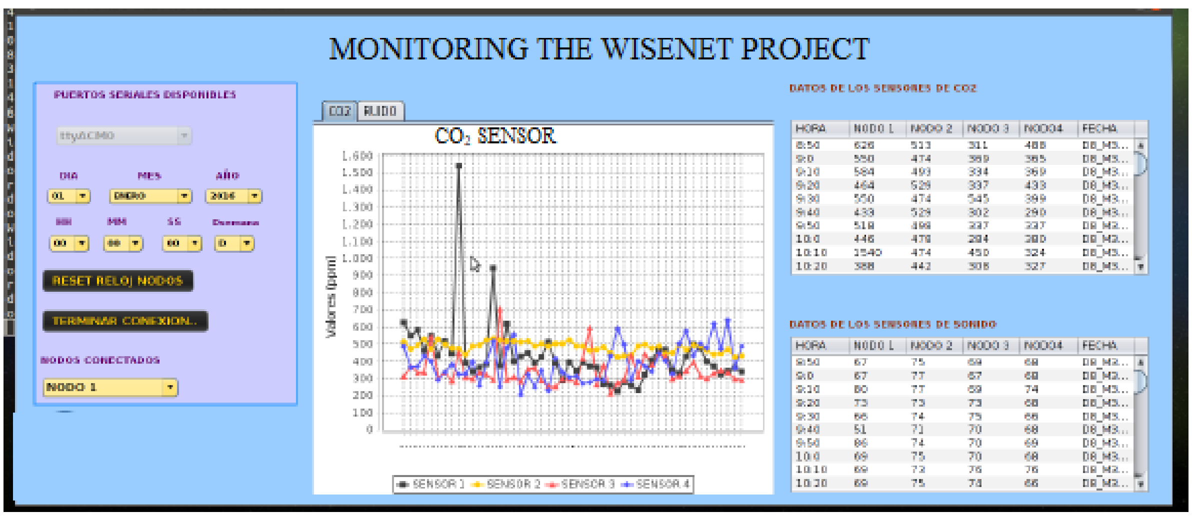

Figure 6 Schematic representation of research project interface during the operation

5. Development of the application for network monitoring in NetBeans

2.5.1. Development of the executable file of the graphical application: The development of the graphical application for handling the received data was carried out in java. It was decided to do it in Java due to the use of free software and the programming language known by the authors and which is easier for programmers of desktop applications.

The "Wisenet Project Monitoring" graphical interface was developed by the NetBeans 8.2 IDE. Which allows us to create an executable of the project created to compile it within the Raspberry pi device, in this way the device resources are not saturated and it does not run the risk of crashing or in the worst case restarting. The ECU911.jar file will be created inside the project folder, just in the subfolder. In Windows operating systems the file can be executed by double clicking, while in Linux operating systems it is necessary to execute it through the terminal. Once this file is created, the project folder must be transferred to the Raspberry. As the device is linked on the ECU911 network, the file transfer can be done via the network. In our case, we have used chrome browser, which is perfect for transferring files within the same network.

2.5.2 Design and operation of the graphical interface: The designed application consists of four parts for its operation. The first part is to establish the connection between the Arduino Mega and Raspberry Pi devices. Communication between these is done serially, which is why the JSerialcomm Java library was used to create the application. With Linux operating systems, communication does not usually exist due to conflicts with this library, it is for this reason that it is advisable to type some commands in the terminal before executing the application so as not to have any problems when establishing the Connection. In the username field, it must be replaced by the username of the computer, in our case the name of pi was assigned in the operating system. Some of these commands fail and this will depend on the derivation of Linux that is used, in which case there is no problem if one fails. Within the development of the application we can establish the connection by pressing the button in this the black box specifies which ports are connected to the Raspberry pi, the option ttyACM0 must be chosen since it is the port to which our Arduino is connected. While the red box specifies the establishment of the connection and must be pressed to initiate the link between the devices. The second part consists of maintaining the synchrony of the network that is, maintaining the measurements in real time in each of the sensor nodes within the network, it is for this reason that an RTC3231 was placed in each one as mentioned above. In the application, the option to reset the time and date was added, this information will be sent to each node so that it performs a set to its respective RTC [Mansour, Samer & Nasser, Nidal & Karim, Lutful & Ali, Asmaa. (2014)]. The format that this function handles within the application is dd-mm-yy for the date while for the time it is hh-mm-ss with the option to choose the corresponding day of the week as we can see the yellow box. The third part is in charge of visualizing the measured data of each one of the nodes. In our case, the database is installed within the same Raspberry device. Because the device is connected to the local area network, it is possible to access the database by entering the IP address [Patil, Shweta & Deshpande, Pradeep (2020)].

Project Development Cost

1. Development cost of the devices of the "WiSeNet" project:

Components and Cost of additional components and tools used in the "WiSeNet" project: Flexible cable AWG 14 (24 mtrs); Ethernet cable (8 meters), Ladder transport (6 times); Electrical extensions, Female-female jumper cable kit for Arduino, Female-male jumper cable kit for Arduino(4NOS each) and the total cost around 92600 IRD. Cost of developing the application for monitoring "WiSeNet" and programming the microcontrollers.is 2054400 IRD

Table 1 Development cost of the devices of the "WiSeNet" project

S.NO	Description	Price (IRQ DINAR)
1	Raspberry Pi 3B (1 NOS)	79608
2	Arduino Mega 2560 (1 NOS)	61525
3	CH340 module (1 NOS)	3477.5
4	Ethernet Switch 5 Port Metal Switch B Link 10/100 (1 NOS)	14980
5	Arduino Nano (4 NOS)	85600
6	RTC 3231 (4 NOS)	32100
7	Mg811 modules (4 NOS)	385200
8	Sparkfun Sound Modules (4 NOS)	42800
9	Lipo Rider Pro Modules (4 NOS)	98012
10	Lithium Polymer Batteries-3.7V-1050MA (4 NOS)	52858
11	Solar Panels 5V- 1W (4 NOS)	32742
12	Regulators 5 to 3.3 V (4 NOS)	4280
13	Relays for 5 V (4 NOS)	2568
14	XBee-PRO® 900 DigiMesh Module (5NOS)	588500
15	5V chargers (5 NOS)	32100
16	Acrylic housings (5 NOS)	160500

Analysis of Results

This chapter shows the results obtained from the CO_2 and Noise measurements in each Node, also describes an analysis of the effect produced by vehicular traffic on the levels measured in each monitoring sector. These analyses are carried out thanks to the graphs that can be obtained with the data stored in the MySQL database.

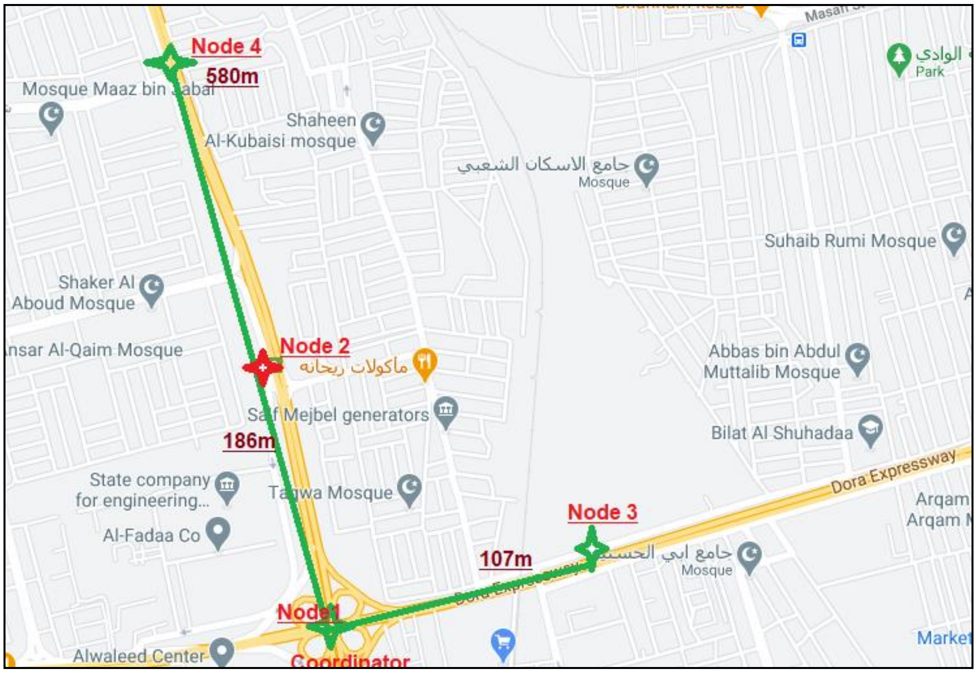

Figure 7 Arrangement of the sensor network within the Dora Express, Highway, and Baghdad, Iraq with distance between Node-Coordinator and height of posts (P). Distance between nodes and coordinator (Image Taken from Google Image)

The objective of the study is to verify the operation and reliability of setting up a network of sensors for monitoring, in this case of CO_2 (ppm) and Noise (dB) in an urban sector. To fulfil this purpose, four sensor nodes and a coordinator are arranged along Dora Express way in the city of Baghdad, Iraq forming a point-multipoint wireless sensor network as shown in figure 7.Both the location and the disposition of each node within the network are governed by the physical architecture of the security camera system belonging to ECU911, the public institution for which the project is developed. The parameters considered for the analysis of the measurements obtained are: Quiet, moderate and high Noise Level, while for CO_2 a typical concentration level [Mansour, Samer& Nasser, Nidal & Karim, Lutful & Ali, Asmaa. (2014)-Luaayabdulwahedshihab, (2015)].

1. Parameters Present in the Monitoring

The measurements taken by the nodes are based on reference levels in their algorithm that are necessary so that the data obtained can be compared with related works and existing measurement equipment[Yi, Wei & Lo, Kin &Mak, Terrence & Leung, Kwong& Leung, Yee &Meng, Mei. (2015)]. Those reference parameters will allow us to make the analysis according to the degree of vehicular traffic existing at the moment of measurement of the sensor nodes and are the following:

- *Quiet noise level:* It is considered the outdoor noise level for values lower than 50 dB.
- *Moderate noise level:* It is considered the noise level that a conversation presents with values greater than 50 dB and less than 80 dB.
- *High noise level:* Level presented by constant vehicular traffic with values higher than 80 dB.
- *Typical CO_2 concentration:* It is considered the typical atmospheric concentration of CO_2 at levels less than 450 ppm (percent per million).

However, factors such as the height and location of each node also intervene in the measurement threshold of the sensors.

2. Analysis of Vehicle Noise and Pollution levels

The table of values pertaining to the CO_2 and Noise measurements with time and date of measurement were extracted from the database and later plotted in Excel. The study will first consider the graph of the database with the measurements of the four nodes and later the nodes separately from the two days of monitoring.

The analysis of the results obtained must take into account the following considerations that are dependent on the location of each Node and the Coordinator:

- **Coordinator:** It is located on Dora Express highway Junction (N 33° 14' 11.1757", E 44° 22' 1.2994"), at a height of 7.2 meters next to No. 1.
- **Node 1:** It is located point opposite to Dora Express, Highway Junctions, at a height of 7.2 meters next to the Coordinator.
- **Node 2:** It is located on the point opposite to Al-Rasheed State Company, at a height of 7.2 meters and 186 meters away from the location of the Coordinator with direct line of sight.
- **Node 3:** It is located on the point opposite to General Authority for maintenance of irrigation projects and drainage, at a height close to 9 meters and 107 meters away from the location of the Coordinator with direct line of sight.
- **Node 4:** It is located point opposite to Rose shops to the Market, at a height of 13 meters and 580 meters with respect to the Coordinator with direct line of sight.
- Data extracted from June 14 and 16 were taken from approximately 9 am to midnight.

Both the nodes and the coordinator are installed on poles, together with the security cameras of the Integrated System ECU911, who provided us with the necessary information to list the aforementioned considerations.

3.2.1. Noise: In Figure 8, 'a' and 'b' contain the Noise measurements for June 14 and June 16 respectively of 2019. It can be clearly observed that nodes one and three are more susceptible to changes in noise levels compared to nodes two and four, which contemplate less variation in their measurements, taking into account the first is not located in a stop and the last is at a fairly high height unlike the others [Hejlová, Vendula & Voženílek, Vít. (2013)-Piedra, Antonio & Benitez-Capistros, Francisco & Dominguez, Federico & Touhafi, Abdellah. (2013)], so the measurement threshold is affected. Despite this inconvenience, the values in peak hours are above 75dB, making it clear that there is greater vehicular activity in those hours and decreasing considerably as midnight approaches. Constant levels above 75 dB indicate constant vehicular traffic and possible congestion [Singla, Tania & Manshahia, Mukhdeep. (2017)-Hejlová, Vendula & Voženílek, Vít. (2013)].

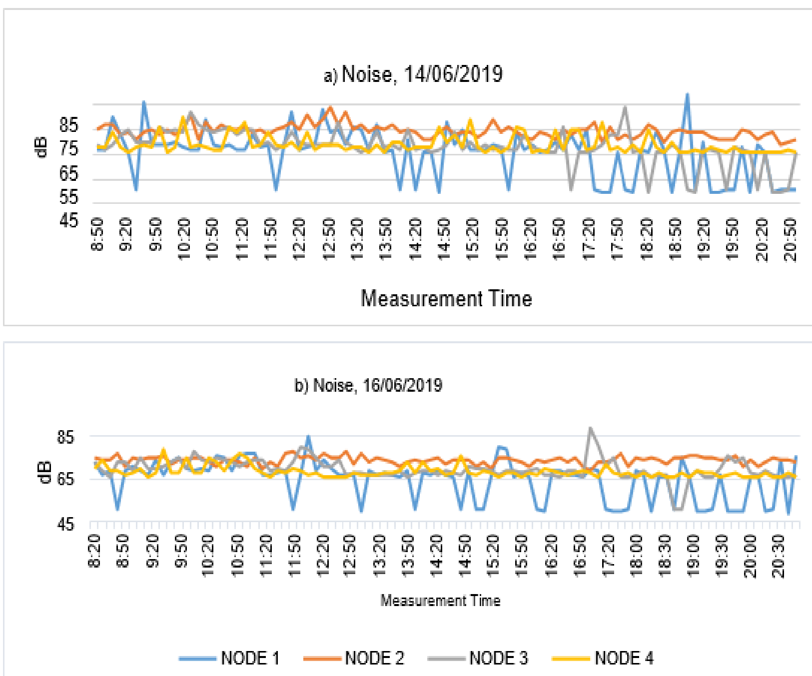

Figure 8 Values extracted from the database a) Noise Levels pertaining to June14, 2020 b) Noise Levels pertaining to June16, 2019

For a better understanding we will analyse the behavior of noise levels per node between the two days of monitoring.

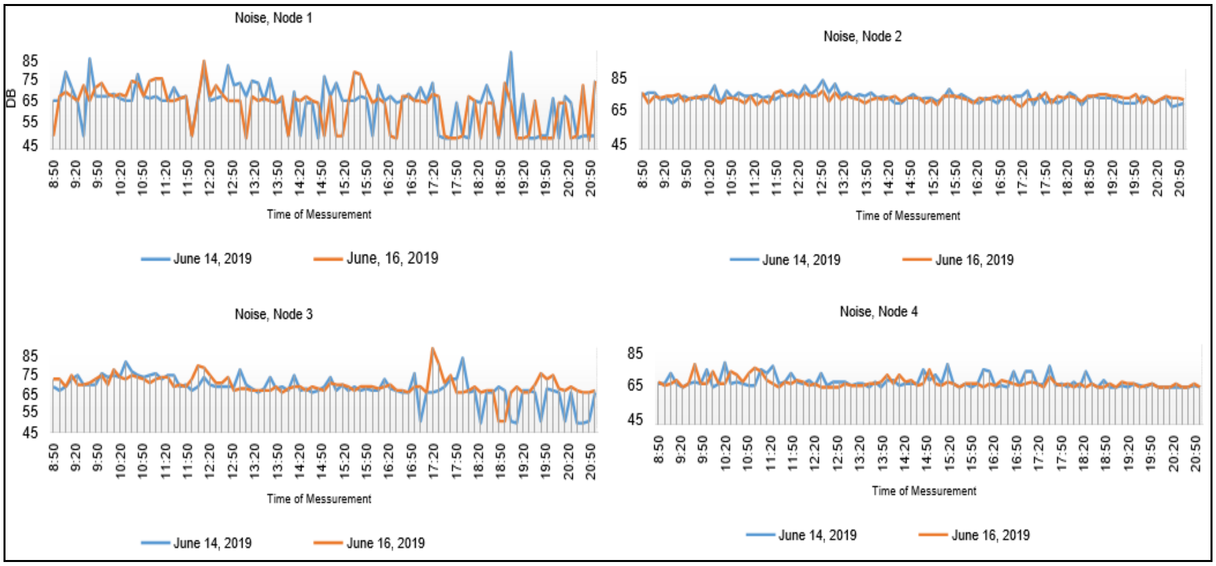

Figure 9 Noise measures taken from 8.50a.m. Node 1 to Node 4 at 8.50 p.m. monitoring in two days (14 and 16 June 2019)

The measurements shown in figure 8 of node 1 are one of the lowest nodes and are built at the motorway connexions Dora Express. It shows clearly that daytime activity is strong and appears to decline by night, but after 8 p.m. on June 16. Although not continuous, operation still exceeds 75 dB, suggesting movement of vehicles. Node 2 across the two calculating days. It presents 75dB levels between 13:00 p.m., located almost at Al-Rasheed State Corporation. And 14:00 and 14:00. On the afternoon, that approves the first node measurements, indicating a possible congestion of traffic or traffic jam in the space of time. Node 3, at 9 metres high, but at an intersection, is comparatively vulnerable to noise measurements. In Figure 9 it can clearly be seen how their levels fell at 8 p.m. It's not constant at night and your measurements. Although the graph gives us a general idea of the vehicular activity generated during the day and night, the height at which the node performs the measurements prevents it from capturing acceptable noise levels to determine that there is some kind of noise at that intersection traffic congestion. Node 4, being located 13 meters high, is the node that is farthest from the noise generation area [Yi, Wei & Lo, Kin & Mak, Terrence & Leung, Kwong & Leung, Yee & Meng, Mei. (2015)- Mansour, Samer & Nasser, Nidal & Karim, Lutful & Ali, Asmaa. (2014)]. Despite being close to vehicle stop, the levels captured are low but acceptable, so that figure 9 clearly shows the relationship between the two measurement days, where, being close to the festive season, it presents higher activity from 9:00 a.m. to approximately 1:00 p.m. and then only on June 14 from 4:00 p.m. to 7:50 p.m.

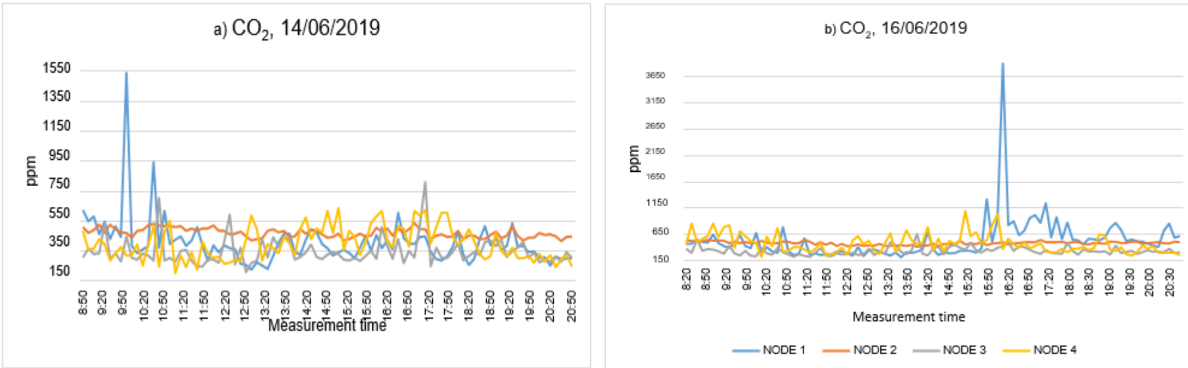

Figure 10 Values extracted from the database a) CO_2 Concentration Levels pertaining to March 14, 2019 b) CO_2 Concentration Levels pertaining to June16, 2019.

Each node measurements are then analysed separately during the two surveillance days. Figure 10 shows the same behavioural pattern with elevated levels of CO_2 during the day, indicating a small decay after 7:00 p.m. as part of CO_2 measurements obtained during the first node. The night of 14 June is longer between 5 p.m. and the next day. At 20.50 p.m. And then it displays high CO_2 concentration values, but they will not be constant until 0:00 unlike the previous day.

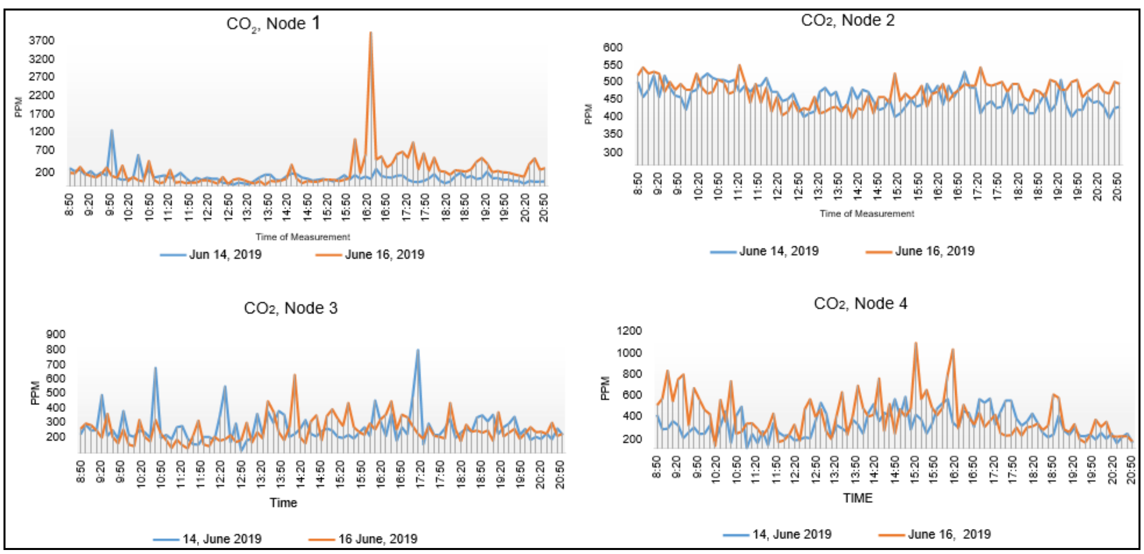

Figure 11 CO_2 Concentration Node1 to Node4 measurements from 8:50 a.m. till 20.50p.m. Two surveillance days forward

The measurements are accurate as from 5:00 p.m. on 16 June. The opening of restaurants and other activities leading to greater vehicular traffic, is leading to a greater influx of people. It is accompanied by a relatively constant level over a certain amount of time rather than by the highest concentration limit. Figure 11 shows two high peaks of 1500 and 3900 ppm, both of which at some point reflect relatively significant carbon dioxide stages but not over point.This suggests a potential automotive damage or industrial accident that at that time resulted in high CO_2 emissions or in some other case. This is because the sensors calculate levels irrespective of the source.The CO_2 concentration calculated in Node 2 makes it clear that the measuring curve is conducting at 9 am to 2 pm at a higher concentration of CO_2 at levels above 450 ppm, which is the same as decreasing after 7 pm. Due to the fact, that Node 2 is not located at exactly one stop/ intersection, as it is the node1 or 3, CO_2 levels give us a better picture of vehicle transport comportment. The figure 11 shows low data obtained from Node 3 relative to the first two Nodes, but does not display strong and persistent CO_2 concentrations at a 9 m high activity. Although the measurements are at an intersection, it is not clear enough that there is potential traffic or congestion if noise levels at the same time are not assisted. The CO_2 levels during the two-day monitoring period range from 400 to 550 ppm, which are low compared with the levels shown by the first node, and are appropriate given that urban transport vehicles emanate higher CO_2 levels.Figure 10 for the CO_2 level acquired in the Fourth Nodes clearly indicates that CO_2 levels are rising in the peak hours of vehicular traffic, with a median of 1100 ppm and a median of 18:00 ppm in the afternoon. The levels measured are smallrelated to the node1, and the vehicle's activity pattern is clearly seen in the graph but with relative low values, since it has a height of 13 metres in terms of the carbon emitted emphasis.

Conclusions

The WSN assembled from the XBee modules is entirely reliable as there was no information interference or loss taking the maximum connecting distance and line of sight conditions into account while the tests were conducted along with the ECU911 Integrated Defence System.

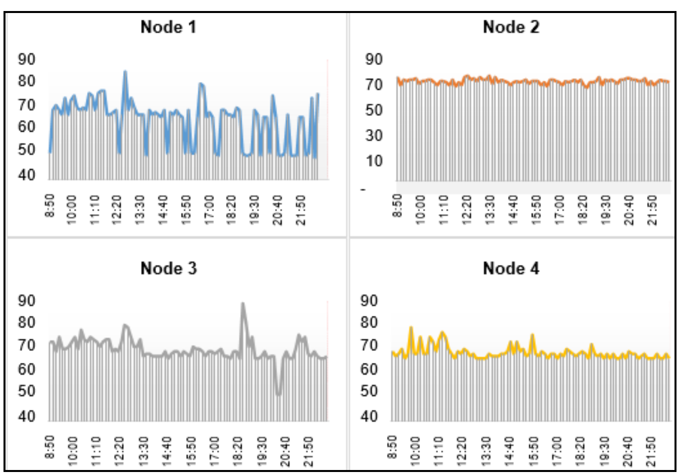

Figure 12 Comparative table of the Noise level taken by the four nodes on June 16, 2019 from 08.50 a.m. to 09.50 p.m. The vertical axis shows the noise variations in dB, while the horizontal axis shows the measurement times

From the comparative table shown in Figure 12 we conclude that the behaviors shown by the noise curves belonging to the first, third and fourth Node present a better performance in terms of the measurements obtained if we consider that both the height and the sensitivity of the sensors are affected in each case. So much so that the second Node does not present variations in its measurements because there is no type of intersection or bus stop where it is installed, which allows it to take a prolonged measurement of the noise emitted. Unlike CO_2 concentrations, the sound after being emitted does not dissipate slowly in the environment, which generates the need to measure and later store the noise level immediately after it is generated. Node 1 includes a situation with the best possible noise and CO_2 control conditions. The activity of the curves is connected to the information needed to assess the increase and decrease in vehicle traffic at particular times in both cases. Both the height and its position in the vicinity of an urban transport stop minimise the study emphasis measuring threshold, so the node can calculate closer to those produced by the source at the exact time when they occur.

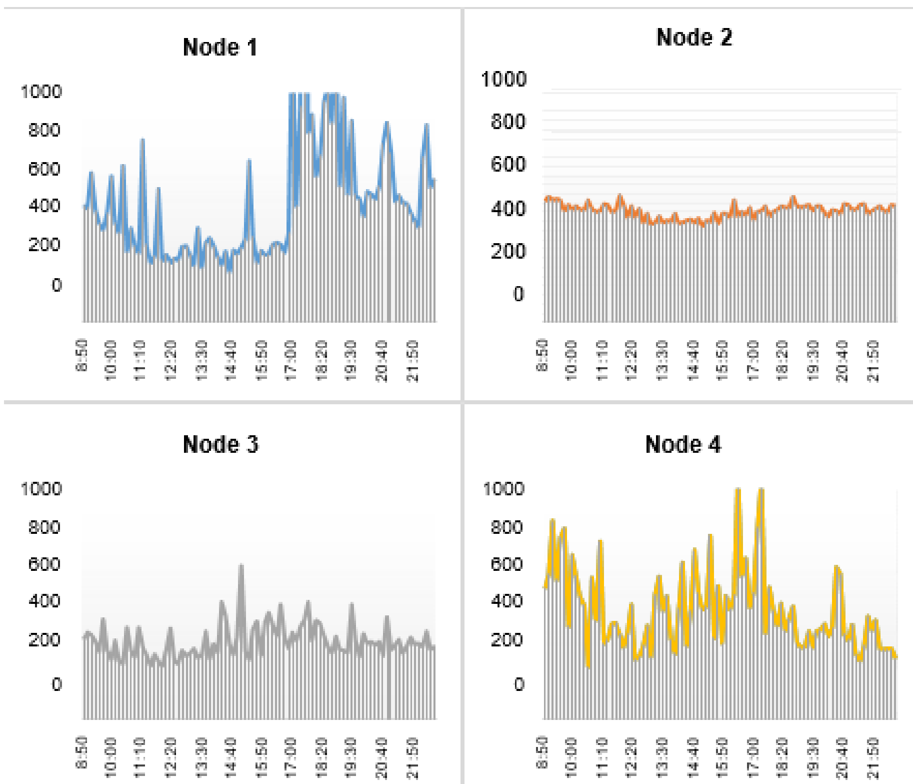

Figure 13 Comparative table of the CO_2 concentration level taken by the four nodes on June, 16, 2019 from 8.50 AM to 9.50PM. The vertical axis shows CO_2 variations in ppm, while the horizontal axis shows the hours of measurement

From the comparative table in figure 13, we conclude that the behavior of the curve described by the levels of CO_2 concentration in the 4 Nodes clearly shows the vehicle activity during the day and night. Regardless of the height at which they are, the first, third and fourth Nodes present higher peaks of CO_2 concentration, a direct consequence of their location shown in Figure 13.As they are situated higher than the first two nodes, the performance of Nodes 3 and 4 is reduced. This factor raises the measurement threshold in order to slightly attenuate the signal produced by the emitter focus before the sensors hit it, which is why the nodes are sending low noise and CO_2, but keeps pattern. Measurement activity showing elevated CO_2 levels and high noise levels at peak hours. The four nodes track the noise or CO_2 concentrations continuously 24 hours a day, irrespective of their source or source. As can be seen from figure 8 with two high CO2 peaks which, since not constant over time, do not provide further details about vehicle operation at the time, the device can therefore only take measurement at an immediate point of time in which any circumstances beyond our study occurs. The Integrated Protection Framework ECU911 is however quite interested in this form of measurement since it is controlled logistically so that problems related to this activity can be solved. The database is at this point important as analyses can be done between days, weeks or months of monitoring. The measurements obtained by the sensor network allow the ECU911 Integrated Security System, at a given time and location, to give priority to a camera to identify the focus of CO_2 concentration or noise emission. In this way, if there is a problem either due to traffic congestion or another factor, you can be assisted immediately.

References

Rahima, A.Q., Tarish, H.A., & Sapih, N. (2018). Monitoring and Control System by Using Wireless Sensor Network for Ground water Well's Field in South of Iraq. *International Journal of Scientific Research in Science and Technology, 4*(11), 311-318. http://doi.org/10.32628/IJSRST18401155

van Steen, M., & Tanenbaum, A.S. (2016). A brief introduction to distributed systems. *Computing, 98*(10), 967-1009. https://doi.org/10.1007/s00607-016-0508-7

Panneer Selvam, Arun Mozhi Devan & Hussin, Fawnizu & Ibrahim, Rosdiazli & Bingi, Kishore & Nagarajapandian, M.. (2019). IoT Based Vehicle Emission Monitoring and Alerting System. 161-165.

Devan, P.A.M., Hussin, F.A., Ibrahim, R., Bingi, K., & Nagarajapandian, M. (2019). IoT Based Vehicle Emission Monitoring and Alerting System. *In IEEE Student Conference on Research and Development (SCOReD),* 161-165. http://doi.org/10.1109/SCORED.2019.8896289

Kakouei, A., Vatani, A., & Idris, A.K.B. (2012). An estimation of traffic related CO2 emissions from motor vehicles in the capital city of, Iran. *Iranian journal of environmental health science & engineering, 9*(1), 1-5. http://doi.org/10.1186/1735-2746-9-13

Kadri, A., Yaacoub, E., Mushtaha, M., & Abu-Dayya, A. (2013). Wireless sensor network for real-time air pollution monitoring. *In 1st International Conference on Communications, Signal Processing, and their Applications (ICCSPA),* 1-5. http://doi.org/10.1109/ICCSPA.2013.6487323

Granda, B.A.B., Belduma, L.A.B., Gonzalez, E.J.C., & Sarango, A.F.S. (2017). Designing a wireless sensor network for vehicular traffic and CO2 pollution monitoring in an urban area. *In IEEE 9th Latin-American Conference on Communications (LATINCOM)*, 1-6. http://doi.org/10.1109/LATINCOM.2017.8240168

Carbon Dioxide Sensor module MG811 (2019). https://robokits.co.in/sensors/gas-sensors/co2-carbon-dioxide-sensor-module-mg811

Shen, C. (2014). An Investigation of a Low-cost CO2 Indoor Air Quality Monitor. http://doi.org/10.13140/RG.2.1.3901.1364

Khedo, K.K., Perseedoss, R., & Mungur, A. (2010). A wireless sensor network air pollution monitoring system. International Journal of Wireless & Mobile Networks, 2(2), 31-45. http://doi.org/10.5121/ijwmn.2010.2203

Singla, T., & Manshahia, M.S. (2013). Wireless sensor networks for pollution monitoring and control. *International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 2*(6), 217-222.

Hejlová, V., & Vozenílek, V. (2013). Wireless sensor network components for air pollution monitoring in the urban environment: criteria and analysis for their selection. *Wireless Sensor Network, 5*(12), 229-240.

Bathiya, B., Srivastava, S., & Mishra, B. (2016). Air pollution monitoring using wireless sensor network. *In IEEE international WIE conference on electrical and computer engineering (WIECON-ECE),* 112-117. http://doi.org/10.1109/WIECON-ECE.2016.8009098

De La Piedra, A., Benitez-Capistros, F., Dominguez, F., & Touhafi, A. (2013). Wireless sensor networks for environmental research: A survey on limitations and challenges. *In Eurocon 2013*, 267-274.

Yi, W.Y., Lo, K.M., Mak, T., Leung, K.S., Leung, Y., & Meng, M.L. (2015). A survey of wireless sensor network based air pollution monitoring systems. *Sensors, 15*(12), 31392-31427. http://doi.org/31392-31427.10.3390/s151229859

Mansour, Samer & Nasser, Nidal & Karim, Lutful & Ali, Asmaa. (2014). Wireless Sensor Network-based air quality monitoring system. 2014 International Conference on Computing, Networking and Communications, ICNC 2014. 545-550.

Mansour, S., Nasser, N., Karim, L., & Ali, A. (2014). Wireless sensor network-based air quality monitoring system. *In International Conference on Computing, Networking and Communications (ICNC),* 545-550. http://doi.org/10.1109/ICCNC.2014.6785394

Patil, S.A., & Deshpande, P. (2019). Monitoring Air Pollutants Using Wireless Sensor Networks. *In International Conference on Computer Networks and Inventive Communication Technologies, Springer, Cham,* 1-8. http://doi.org/10.1007/978-3-030-37051-0_1

Shihab, L.A. (2015). The Mechanism of Congestion between the Server and Clients in a Local Area Network Solutions. *International Journal of Civil Engineering, Construction and Estate Management, 3*(3), 63-68.

Shihab, L.A.W. (2012). Wireless LAN Security and Management. *International Journal of Engineering and Advanced Technology (IJEAT), 2*(1), 314-317.

Shihab, L.A. (2020). Technological Tools for Data Security in the Treatment of Data Reliability in Big Data Environments. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 11*(9), 1-13. http://doi.org/10.14456/ITJEMAST.2020.175