Proposed Prototype and Simulation of Wireless Smart City: Wireless Sensor Network for Congestion and Flood Detection in Makassar

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***Abstract*—Urban issues become more complicated and complex as the city grows, requiring better management to create a comfortable, safe, sustainable, and sustainable city atmosphere. Implementing the concept of smart city is one solution that can be used to perform better management of the city. Many major cities have started the development of smart city, including Makassar. The development of infrastructure to support the implementation of smart city in Makassar has been going on at this time, such as the addition of Wifi Corner in several points of Makassar. The technology that can be applied in supporting smart city infrastructure is wireless sensor network. This research resulted a design of wireless sensor network by utilizing the wireless public infrastructure that has been available in the city of Makassar today. The design is simulated by involving 2 sensor nodes, 1 gateway sensor node, and public wireless network. Each sensor node obtains the environment values, such as temperature, humidity, CO_2, and water level. The environment values are sent to the server by the sink node. The process of sending sensor data based on requests from the server automatically and periodically to avoid network congestion on the wireless public network. All data will be displayed to be a decision support for the Government of Makassar City in anticipating the problems of the city, such as traffic congestion and floods. The design of wireless sensor network is expected to become the main infrastructure as a supporting component of smart city in Makassar using public infrastructure. The obtained data from WSN are expected to be processed using artificial intelligence's algorithms to provide the useful information to users using the public infrastructure.**

Keywords—smart city, public infrastructure, wireless sensor network, data monitoring

I. Introduction

The growth of cities in the world that exceeds 50 percent causes problems in the city to become more complex, such as congestion, flooding, garbage, and other things, so that better management is needed to make the urban people still feel comfortable, safe, growing and sustainable [1]. This is also applies in Makassar as the capital of South Sulawesi province. Based on the results of the Indonesian Politician Ambassador's survey, quoted from Tribun Timur (2015), the important issues in Makassar are crime, traffic congestion, hygiene, education and economy. The Mayor of Makassar, Mohammad Ramdhan Pomanto, quoted from Antaranews (2016), has launched the concept of Makassar Smart City combined with the local wisdom (Sombere) to overcome that important issue.

Major cities have started the development of smart city today, like Seoul, New York, Tokyo, Shanghai, Singapore, Amsterdam, Cairo, Dubai, Kochi and Malaga [2]. Cities are becoming smart not only in terms of the way we can automate routine functions serving individual persons, buildings, traffic systems but in ways that enable us to monitor, understand, analyse and plan the city to improve the efficiency, equity and quality of life for its citizens in real time [3].

The future cities must have the high-quality infrastructure and to be well led and well managed to provide the best services, quality of life, economies and jobs [4]. The infrastructure development has been going on at this time in towards the concept of Makassar Smart City, some of them is the increasing the number of Wifi Corner at some point in Makassar. In addition to infrastructure development, there are also some services that have been implemented in Makassar, such as telemedicine services and home care Dottoro'ta.

Smart city is related with technologies that can generate the data of city and also allow interaction on each of its elements [5]. In this regard, the integration between infrastructure in a city is also one part of the implementation of the smart city. The infrastructure of modern city must be robust, resilient and adaptable to changing patterns, particularly natural disasters and climate change. It also needs to be optimised in terms of efficiency, cost, low carbon footprint and service quality so that can benefit enormously which involves the innovative use of emerging technologies in sensor and data management [4].

Wireless smart city can be defined as the entire Information Technology infrastructure and smart city program in a city can be implemented and accessed through wireless devices. The communication between wireless devices in wireless smart city utilize the public or private infrastructure. Wireless technologies have been developing rapidly in these years. The obvious advantage of wireless transmission is a significant reduction and simplification in wiring and harness [6]. Makassar as one of the city that is developing smart city concept can go towards wireless smart city because the number of wifi corner in Makassar city based on Telkom have reached 654 point so the smart city applications can be accessed by connected devices using wireless connection and internet.

The technology that can be applied in wireless smart city infrastructure is wireless sensor network (WSN) [5] [7]. The use of wireless sensor technology can provide significant

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benefits for monitoring the city infrastructure. WSN consist of a large number of sensor nodes and are used for various applications, such as building monitoring, environment control, wild-life habitat monitoring, forest fire detection, industry automation, military, security, and health-care [8]. Future smart sensor systems in city infrastructure will undoubtedly comprise wireless sensor networks as part of the internet of things and will be designed around the capabilities of autonomous nodes [4]. The implementation of wireless sensor network technology in Makassar will help in realizing the concept of smart city that has been planned. The benefits that can be obtained with the implementation of wireless sensor network is monitoring and information about traffic congestion and flooding on the streets can be known by processing data from temperature, carbon dioxide, and water level sensors.

In addition, the obtained data of road conditions data from WSN can be used as input from several algorithms that have been developed in previous research to produce the shortest path by considering the real-time road conditions. In this case, there is a difference between Google Traffic and the data collection from WSN. Google Traffic uses crowdsourcing to move the user's GPS from one location to another to get the road condition. Google Map uses crowdsourcing to obtain road conditions by collecting and analyzing the movement of users via GPS that moves from one location to another [9], whereas the data from WSN is expected to produce a route by considering the results of the sensor data collection. The data of road situation can be processed using the artificial intelligence's algorithms, such as the shortest route algorithm in previous research, for example, the collaboration of Ant Colony System (ACS) and the result of clustering k-Means to profiling and predict road situations, and Fuzzy ACS (FACS) algorithms that collaborate the result of Fuzzy Inference System and ACS to obtain the shortest route based on real time traffic conditions [10].

II. Related Work

Sanchez-Rosario et al (2015) implemented a wireless sensor network for environmental monitoring systems. The monitoring system developed involves automatically inputting the data from the sensor, transmitting with low bandwidth usage from the node sensor to the gateway sensor node, storing data into the database, and monitoring in real time through the web server. The sensors used in this study are on a board called The Smart Cities Sensor Board. The used sensors for environmental monitoring are sensor particles of dust, humidity, temperature, and sound [11].

Braem et al (2016) designed the real time monitoring system for monitor air quality. The data of air quality were obtained from sensors on the top of the van that surrounds the city of Antwerp (Belgium). Sensor data can capture VOC, CO_2, temperature and humidity values and is equipped with GPS location. The sensor data of each GPS location are then visualized and integrated with devices with wireless technology [12].

Sturari et al (2016) utilizes real time data from traffic monitoring results from the camera. This research uses wireless sensor network where every node is cameras and integrated with Geographic Information System. This research uses Simulation of Urban MObility (SUMO) for system simulation process [13].

Siregar et al (2016) designed the integrated monitoring system using a wireless sensor network to monitor the air pollution. This study uses several sensors, such as dust particle sensor, humidity sensor, temperature, light, and audio. The communication protocol used is 3G with data storage to the cloud system. The results of storing sensor data into the database server can be used by the governments and policy makers as basic information to take further action to reduce air pollution levels [14].

III. Design of Wireless Sensor Network

Wireless sensor networks are used for data collection, processing and transmission consisting of a collection of nodes and base stations. A node consists of processor, local memory, sensors, radio and battery. The base stations have the responsibility to receive and process data collected by nodes [15].

The wireless sensor network has sensor nodes, which consists of four components, namely the detection unit, the processing unit, the transceiver and the power unit. In addition, there is sink nodes that are responsible for collecting information wirelessly [16].

The architecture of WSN consists of Infrastructure (related to the current sensor and deployment status), Network Protocol (are responsible for creating paths and communication between sensors, base stations and users), and Applications (display the information that can be obtained by users regarding the data that they want to monitor and reporting data with certain patterns that can be static or dynamic) [17].

A. *Infrastructure*

1) *Design of Node*

In this research, the simulation uses 2 (two) sensor nodes and 1 (one) sink node. The sink node is responsible for collecting data from the sensor node and sending the data to the server. Each sensor node has a certain coverage area and has tasked to obtain data of the environmental conditions, such as temperature, humidity, CO_2 level, and water level, by using Arduino Uno or Wemos and several sensors, such as DHT11, MQ-9, and water level sensors.

DHT11 sensor is used to capture the temperature and humidity values in the covered area. The higher value of air temperature and humidity it can be said that there are many vehicles passing by in the area. This happens because the heat released by the vehicle affects the temperature and humidity of the air in the path that it passes.

The MQ-9 sensor is used to capture CO_2 level in the air of the node sensor's covered area. The higher value of MQ-9 sensor, the higher the CO_2 level, which means that there are many vehicles because more vehicle fumes are going through the streets.

The water level sensor is used to measure the height of the water in the coverage area of sensor node. The higher value of the water level sensor means that the higher the pool of water on the street.

Each sensor node is equipped with an ESP8266 module for communication to a public network access point. Each sensor node will have and store a static IP and coordinates its location and is stored in the database server. The block diagram of sensor nodes can be seen in Fig. 1.

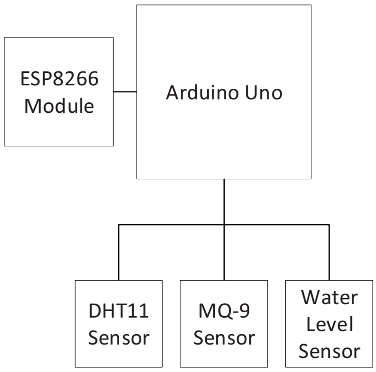

Fig. 1. Block diagram of sensor node

In addition to sensor nodes, there is also sink node. The sink node aims to gather information from several sensor nodes from a particular area. After collecting the information from sensor nodes, the sink node provides the information to the server. In this research, there is a LED to indicate whether the sink node is connected to the server or not. The block diagram of sink node can be seen in Fig. 2.

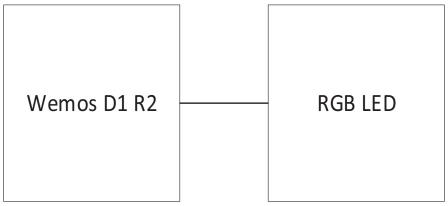

Fig. 2. Block diagram of sink node

2) Network Architecture

All sensor data obtained from the node will be stored on the server and connected via the internet network. The communication between server and sink nodes, and also sink nodes and sensor nodes, utilizes the public network provided by Telkom, namely wifi.id. Wifi.id is a wireless network or hotspot provided by Telkom to provide internet services to the public. This service provides internet access to the public, both around the house and in the public space.

In this research, the designed wireless sensor network utilize public networks wifi.id. The use of public networks is because there are already 654 points of wifi.id in the city of Makassar (based on data from Telkom, as of April 1, 2017). With so many public network points, it can be used to minimize the cost of building private wireless networks for the implementation of wireless sensor networks. The designed of network architecture in this research can be seen in Fig. 3.

In Fig. 3 can be seen that the sensor node (Arduino Uno) will connect to the nearest public access point. Each node sensor will obtain a static IP from the connected access point (Access Point A and B). The sink node also connect to another public access point (Access Point C). The assumption that can be obtained is the internet network on the public access point comes from the same provider so that they can be connected to each other. So, the sensor nodes connected to Access Point A can communicate with the sensor nodes in Access Point B.

Sink node (Wemos D1 R2) is responsible for coordinating sensor data from the nearest node sensor. At the sensor node gateway there is an RGB LED that aims to provide a sign of whether or not a data request is occurring. If the server is requesting data then the light will turn into green, otherwise it will turn into red. When a data request occurs from the server, the gateway sensor node will automatically call the web server of each coordinated node sensor. Both sensor nodes and sink nodes must follow the communication protocol that will be explained in Section Network Protocols for data exchange communication in the wireless sensor network.

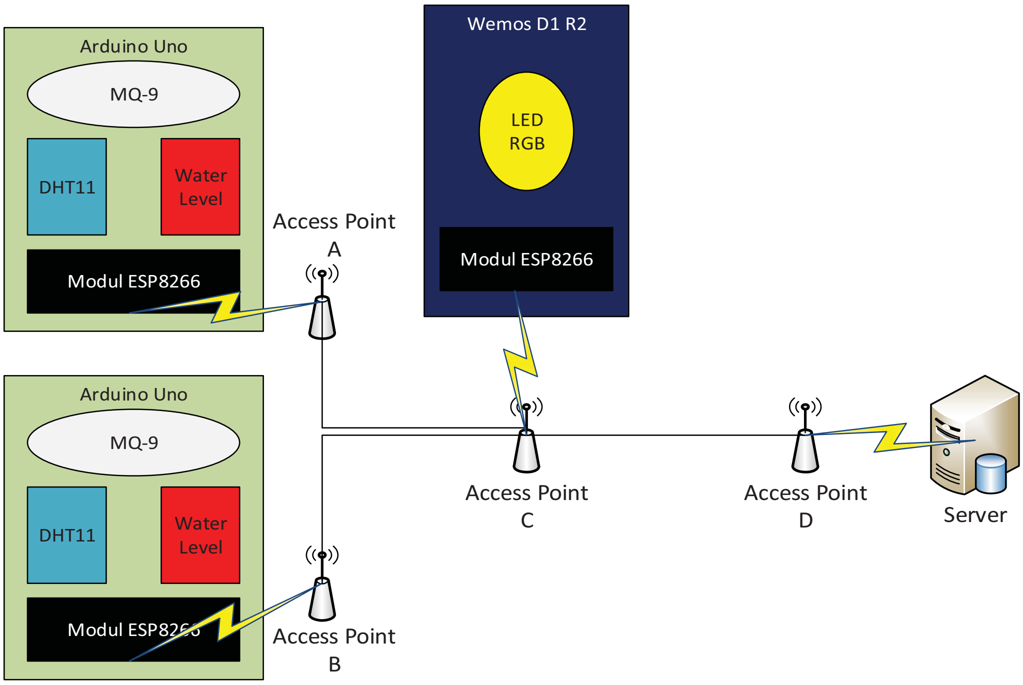

Fig. 3. Design of network architecture of wireless sensor network

3) Node Algorithm

In this research, the wireless sensor network is designed to be connected to the public network so that the security and prevention is needed to prevent network congestion. In this study, we tried to create an algorithm to avoid this. The data request process in this research comes from a server automatically and periodically, unlike in general wireless sensor network where all data will be collected and sent by the sink node to the server (Fig. 4) automatically and periodically.

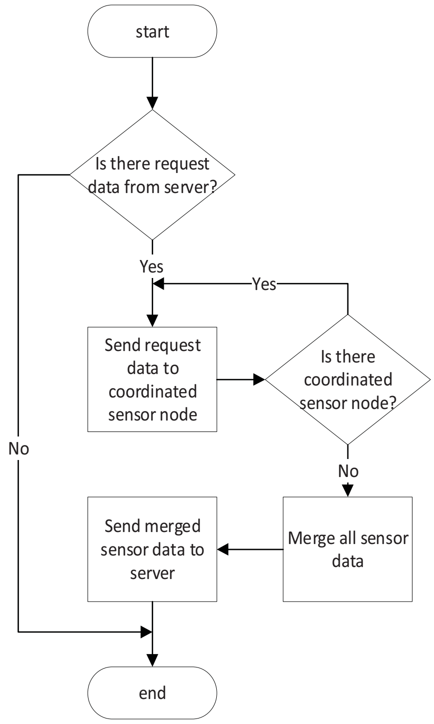

Fig. 4. Sink node algorithm

All static IP address that are owned by the sink nodes and sensor nodes are recorded in the database server. In the database, each sink node records which sensor node will be coordinated in data collection. When the server requests data, the sink node sends data requests on the coordinated sensor nodes automatically. The coordinated sensor nodes by the sink node will capture and transmit sensor data to the sink node (Fig. 5). The sink node then sends all data from the sensor node to the server and will be stored in the database server.

B. Network Protocols

The communication protocol used in this research has the following format:

NILAI SENSOR
 [IP address]
 [CO_2 levels]
 [water level]
 humidity
 air temperature. For example the data sent by sensor node can be seen in Fig. 6.

In Fig. 6, the meaning of the data sent by sensor node is:

NILAI SENSOR : header of protocol

192.168.1.200 : IP address of sensor node

48 : CO_2 level in sensor node

3 : water level in sensor node

84 : humidity in sensor node

32 : air temperature in sensor node

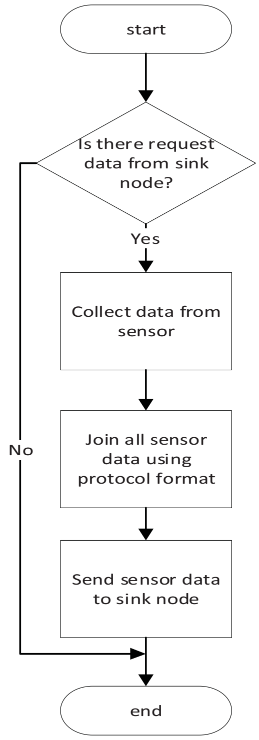

Fig. 5. Sensor node algorithm

The communication protocol between sink nodes and servers is basically same as Fig. 6 but has a difference where all values from the sensor node will be merged. For example, the data sent by the sink node to the sensor can be seen in Fig. 7, it can be seen that there are 2 (two) types of data obtained from the sensor node with IP address 192.168.1.200 and 192.168.1.201. All these data represent the sensor values from the area covered by each sensor node.

```
NILAI SENSOR :
192.168.1.200
48
3
84
32
```

Fig. 6. Data format of sensor node

```
NILAI SENSOR :
192.168.1.200
48
3
84
32
NILAI SENSOR :
192.168.1.201
327
1
78
29
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Fig. 7. Data format of sink node

C. Application

The dashboard application is designed to provide the information in the form of graphs of the movement of sensor data, and the connection status of sensor nodes and sensor sink. In addition, each sensor node and sink node has the GPS data position to facilitate the maintenance process.

Fig. 8. Graph data of Sensor Node 1

IV. RESULT AND DISCUSSION

The testing process of the wireless sensor network design is done by monitoring the results of sensor data collection. The testing process is done on the period of 27-28 April 2017 with the duration of the sensor data acquisition is 60 seconds or 1 (one) minute.

The testing process is done by providing stimulus to the sensor to find out whether the sensor works well in data collection. Stimulus is given in the form of water with a certain height on the water surface sensor, raising the CO_2 in the air by turning the vehicle around the sensor node, as well as the measurement of temperature and humidity during the test. The display of sensor data from Sensor Node 1 and Node 2 Sensor can be seen in Fig. 8 and Fig. 9.

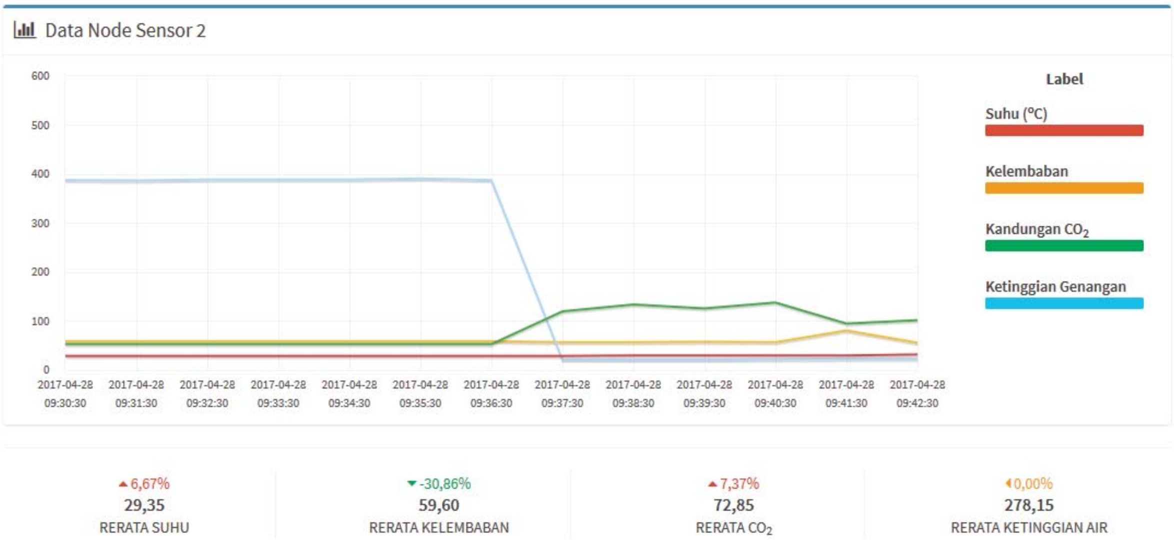

Fig. 9. Graph data of Sensor Node 2

In Fig. 8 and Fig. 9, it can be seen that when the sensor receives the stimulus there is movement of the sensor value. For example, when the water level sensor receives a water stimulus with a certain height, it increases the sensor value from low to high. The same thing applies when the MQ-9 sensor is given a stimulus with the ignition of the vehicle around the sensor.

The design of wireless sensor network that is assisted by monitoring application of sensor data and utilizing Wifi Corner or public infrastructure is expected to give information to the Government of Makassar City to detect the location of congestion and flooded area. As an illustration, if there is an increase in water level data value on Node Sensor 1 then the city government can know the location of the flooded area because each sensor node has the location coordinate point.

The other contribution that can be given in this research is that the collected data can be used as input to the artificial intelligence algorithms to produce useful information to users. One of the useful information for urban society is the information of shortest route by considering the real time road conditions. The data of road condition from the wireless sensor network can be processed to generate traffic predictions using Artificial Neural Network, clustering of road condition using k-Means, fuzzy sets and inference system, determination of the shortest route, and many artificial intelligence algorithms.

V. Conclusion and Future Works

The conclusion that can be obtained from this research is wireless sensor network by utilizing existing public infrastructure in Makassar can become the supporting component of the implementation of wireless smart city. The simulation results show that collecting data from WSN will help to monitor the road condition in Makassar. In addition, the obtained data from WSN are expected to be processed using artificial intelligence algorithms to provide the useful information to users using the public infrastructure.

The testing of the WSN network still needs to further investigation, such as the distance between sensors and the strength of the public infrastructure signal. Further research is planned is the addition of services in support of the application of wireless smart city, such as the route selection application.

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References

[1] S. Supangkat, “Smart City Indonesia”, Smart City ID, Vol 1 July 2015, 2015, pp. 1-5.

[2] J. S., Hwang, and Y. H., Choe, “Smart Cities Seoul: A Case Study”, ITU-T Technology Watch, 2013.

[3] M. Batty, K. W. Axhausen, F. Giannotti, A. Pozdnoukhov, A. Bazzani, M. Wachowicz, G. Ouzounis, and Y. Portugali, “Smart cities of the future,” The European Physical Journal Special Topics 214, 2012, pp. 481-518.

[4] R. Mair, “How will city infrastructure and sensors be made smart?”, Cambridge: The Cambridge Centre for Smart Infrastructure and Construction, 2015.

[5] T. Gea, and J. Paradells, “Smart cities as an application of Internet of Things: Experiences and lessons learnt in Barcelona,” 2013 Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2013, pp. 552-557.

[6] M. Xu, L. Ma, F. Xia, T. Yuan, J. Qian, and M. Shao, “Design and Implementation of a Wireless Sensor Network for Smart Homes,” Ubiquitous Intelligence & Computing and 7th International Conference on Autonomic & Trusted Computing (UIC/ATC), 2010 7th International Conference on, 2010, pp. 239 – 243.

[7] International Electrotechnical Commission, “Internet of Things: Wireless Sensor Networks”, Geneva: White Paper, 2014.

[8] T. V. Chien, H. N. Chan, and T. N. Huu, “Operation System for Wireless Sensor Networks and An Experiment of Porting Contikios to MSP430 Microcontroller,” Journal of Computer Science and Information, Vol 5, 2012, pp. 50-56.

[9] M. D. Al-Amin, and, M. Uddin, 2015, “Real Time Traffic Monitoring System Using Crowd Sourced GPS Data,” Doctoral Dissertation, BRAC University.

[10] E. A. Lisangan, and S. C. Sumarta, “Route Selection based on Real Time Traffic Condition using Ant Colony System and Fuzzy Inference System,” 2017 3rd International Conference on Science in Information Technology (ICSITech), 2017, pp. 66-71.

[11] F. Sanchez-Rosario, D. Sanchez-Rodriguez, J. B. Alonso-Hernandez, C. M. Travieso-Gonzalez, I. Alonso-Gonzalez, and C. Ley-Bosch, C. “A Low Consumption Real Time Environmental Monitoring System for Smart Cities based on ZigBee Wireless Sensor Network,” 2015 International Wireless Communications and Mobile Computing Conference (IWCMC), 2015, pp. 702-707.

[12] B. Braem, S. Latre, P. Leroux, P. Demeester, T. Coenen, and P. Ballon, “Designing a smart city playground: real-time air quality measurements and visualization in the City of Things testbed,” 2016 IEEE International Smart Cities Conference (ISC2), 2016, pp: 1-2.

[13] M. Sturari, L. Catani, A. Mancini, and E. Frontoni, “An integrated mobility system using real-time data for traffic simulation,” 2016 12th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA), 2016, pp. 1-6.

[14] B. Siregar, A. B. A. Nasution, and Fahmi, “Integrated Pollution Monitoring System for Smart City,” 2016 International Conference on ICT for Smart Society, 2016, pp. 49-52.

[15] Santoshkumar, and R.Y. Udaykumar, "Development of WSN system for precision agriculture," 2015 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS), 2015, pp. 1-5.

[16] C. Hernández, and J. Vicente, “Redes inalámbricas de sensores: Una nueva arquitectura eficiente y robusta basada en jerarquía dinámica de grupos”, Doctoral dissertation, Editorial Universitat Politècnica de València, 2010.

[17] S. Tilak, N. B. Abu-Ghazaleh, and W. Heinzelman, “A Taxonomy of Wireless Micro-Sensor Network Models”, Mobile Computing and Communications Review, 2002, Vol 1 No 2.