Wireless Sensor Network for Prototype of Fire Detection

Raditya Budi Nugroho[1], Erwin Susanto[2] and Unang Sunarya[3]
[1,2,3]Engineering School, Telkom University
Bandung 40257, Indonesia

[1]radityabudinugroho@gmail.com, [2] erwinelektro@telkomuniversity.ac.id, [3]unangsunarya@telkomuniversity.ac.id

***Abstract*- This paper proposes the prototype design of a fire suppression system. The system uses temperature sensor LM35, gas sensor MQ-7 and microcontroller ATMega8535 as processing data from sensors. Environmental conditions such as temperature and CO gas concentration will be processed by the microcontroller and the data is sent by XBee Radio Frequency (RF) module and forwarded to the XBee RF server. The User Interface Guide (GUI) on a Personal Computer (PC) displays the data. Fire detection system equipment using Wireless Sensor Network (WSN) is applied with a mesh topology using XBee RF module series 2.**

Keywords— Wireless Sensor Network, Microcontroller, LM35, MQ-7, LCD, GUI, Mesh Topology, Xbee Series 2

I. INTRODUCTION

Fire is one of the environmental threats that can damage humans and their property. Initial information about the potential fire will greatly help in fire prevention. Therefore, a detection device and early warning of fire which provide early information to act more quickly and precisely is required. Wireless Sensor Network, or commonly abbreviated as WSN, is one example of the proper method for detection and early warning of fire. WSN also been widely used in the world of medicine, military, and industry.

WSN is a low powered and small device with inexpensive sensor which able to detect events in the surrounding environment. Each sensor or node will form a distribution of sensors. The data will be sent to the next nearest node and it continues to other nearest node until reach the server node that connected to monitoring device of Windows-based laptop.

This research uses wireless communication protocol standard for radio waves (RF) IEEE 802.15.4 developed by Zigbee to monitor the real-time parameters, like fire and smoke. The objective of this research is to design and implement WSN for fire detection using ZigBee RF communication module. The designed system uses five XBee Series 2 RF modules with mesh topology; four modules for node sensors and one for coordinator node.

II. LITERATURE REVIEW

In WSN networks, nodes sensor deployed with the aim of capturing the presence of investigated symptoms or phenomena. The number of deployed nodes can be determined according to the needs and depends on several factors such as the area, the ability of sensing nodes, etc. Each node has the ability to collect data and forward to the Access Point as well as communicate with other nodes. Nodes sensor can collect large amounts of data from the arising phenomenon of the surrounding environment [7]

WSN architecture can be represented by figure 1. Typical architecture of WSN below

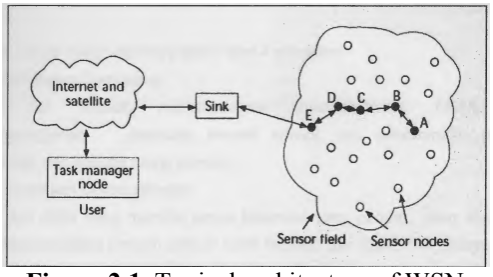

Figure 2.1. Typical architecture of WSN

A sensor node usually consists of four subsystems: computing, communication, sensing and power supply. Computing subsystem consists of a microprocessor (microcontroller, MCU) which is responsible for the control of sensors and implementation of communication protocols, and a memory space. Communication subsystems has a radio frequency with a short range, which is used to communicate with the closest nodes sensor and the physical world. The radio can operate in the transmit mode, receive, idle or sleep depending on the desired activity. When the nodes sensor are not in a state of transmitting/receiving, it is recommended to enable nodes in perfect condition shutdown rather than sleep or standby because both modes consumes considerable energy. Sensing subsystem is a group sensor as the connector between the nodes with the world around.

To achieve minimum energy use, the components mounted on the sensor must have low power.

The main components of WSN to operate are transceiver, controller, sensor, memory, and power supply [6]. Transceiver is used to receive / send data using the protocol IEEE 802.15.4 or IEEE 802.11b to other devices such as RF modules, GSM modem, or other nodes. Controller is used to perform arithmetic and logic calculations which very useful in a variety of data process, such as sending, receiving, set the sleep mode, etc. Usually, the microcontroller is used in this component because it has the capability of processing arithmetic and logic, and also has the ability to store data in RAM. Memory can serve as data storage media optionally because the storage medium is already available on the microcontroller. Sensor acts as a tool to detect physical quantities in the real world. The sensor is a device that can convert a physical quantity into electrical quantities, such as voltage or current, converted by ADC into a quantized pulse that can be further processed by a microcontroller.

ZigBee [8] is a synonym for Zig-zag motion and Bee, they can move erratically in the absence of information about honey from each bee to another. ZigBee technology is a low data rate focus, low power consumption, low cost, wireless networking protocol targeted for automation and remote control applications. Committee of IEEE 802.15.4 works on standard low data rate, then the Zigbee Alliance and the IEEE decided to join. Zigbee is a commercial name (trademark/brand name) for this technology. The IEEE 802.15.4 protocol focuses on two layers down, physical and MAC layer. Zigbee Alliance focuses on dealing with the top layer protocol (from the Network to the Application Layer) for the data network interoperability, security services, and coverage of wireless home and building control, standards prevailing in the market and scientific development to standards evolution.

ZigBee has 3 models of network topology: star topology, Mesh (Peer to Peer) and Cluster Tree

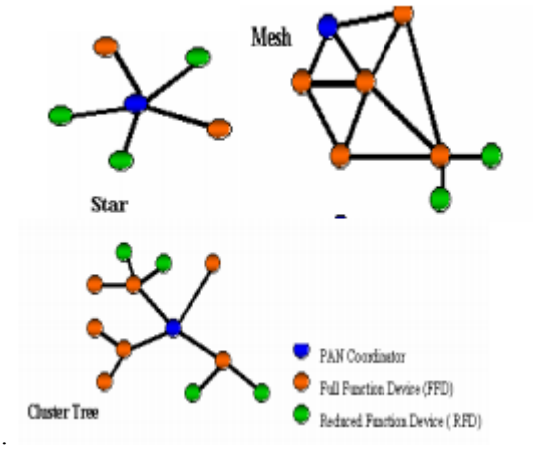

Figure 2.2 Topology Network Model

XBee wireless module communicates in full duplex and operates on the 2.4 GHz frequency range [4].

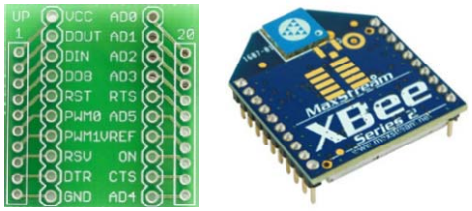

Figure 2.3 Xbee series 2

ATMega 8535 microcontroller is 8-bit microcontroller with 8 Kbyte System Programmable Flash from ATMEL. Memory technology is with RISC (Reduce Instruction Set Computing), no sumirna (nonvolatile), high density, compatible pin out, and accordance with instruction standards set of INTEL.

Figure 2.4 ATMega8535

IC LM35[3] is used as temperature sensor, packed in the form of the Integrated Circuit (IC), which the voltage output is highly linear corresponds to temperature changes. This sensor serves as a modifier of physical quantities from temperature to voltage which has coefficient of 10 mV/° C. IC LM35 does not require calibration or adjustment from the outside due to their accuracy over a quarter degrees Celsius at room temperature.

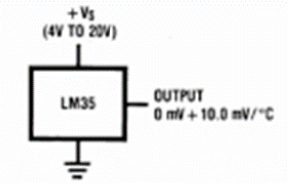

Figure 2.5 LM35 basic temperature sensor

MQ-7 is a CO (Carbon Monoxide) gas sensor, fairly easy to use. Sensors really suitable for the detection of CO gas with a range of detection from 10 to 2,000ppm [1].

Figure 2.6 MQ-7 CO gas sensor

III. SYSTEM DESIGN

In this study, we design a fire detection system using ZigBee RF module using mesh topology. The system can sign if any fire is detected and monitor temperature and the concentration of smoke (carbon monoxide gas). The design is including temperature sensor (LM35) and smoke sensor (MQ7), LCD circuit, minimum system and XBee device.

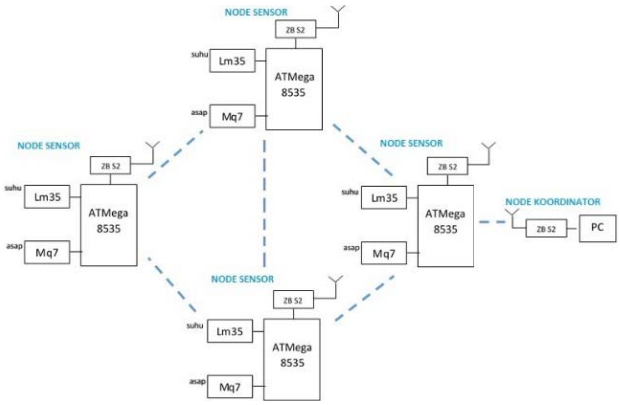

Figure 3.1 System diagram block

The flowchart of designed system and its network architecture can be figured as follows :

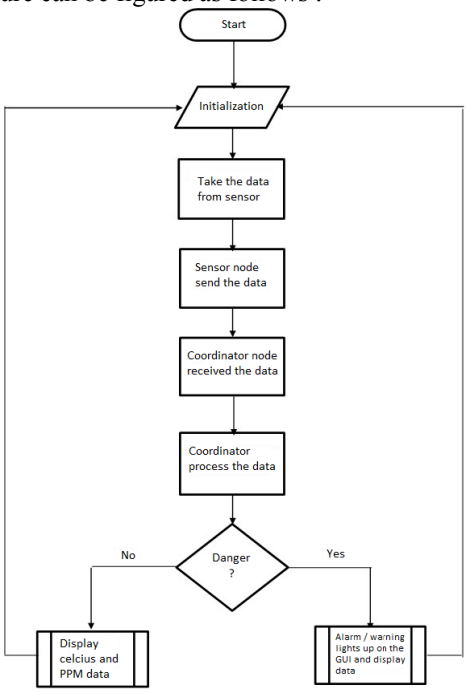

Figure 3.2 Flowchart

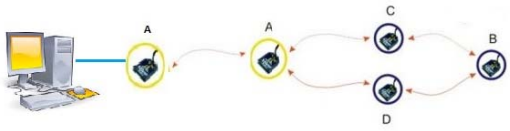

Figure 3.3 Network Architecture

The flowchart of sensor node and sensor coordinator can be figured below

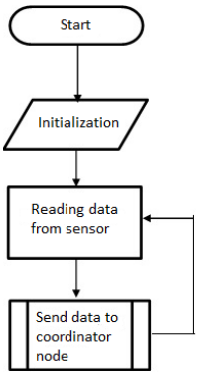

Figure 3.4. Flowchart of sensor node

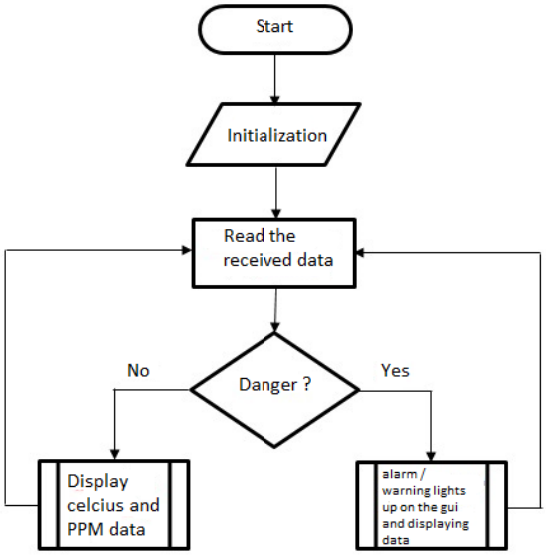

Figure 3.5 Flowchart of node coordinator

The output voltage of the sensor is scaled linearly with the measured temperature, which is 10 mV per 1°C. The output voltage is read by microcontroller through ADC pin without the need of a booster. Hence, the conversion of the ADC into temperature units requires the following calculation:

$$^{0}C = \frac{ADC \times 5000mV}{1024 \times 10}$$

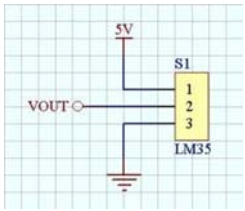

Figure 3.6 Schematic of LM35

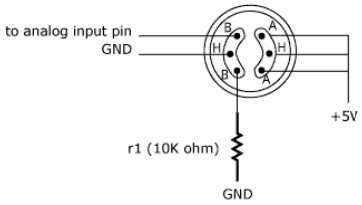

Figure 3.7 Schematic of MQ-7

The sensor can detect CO gases between 20-2000 ppm (parts per million). Smoke must contain CO gas that is needed for the calculation for the value of ADC conversion into units of ppm

$$ppm = \frac{ADC \times 1980}{1024} + 20$$

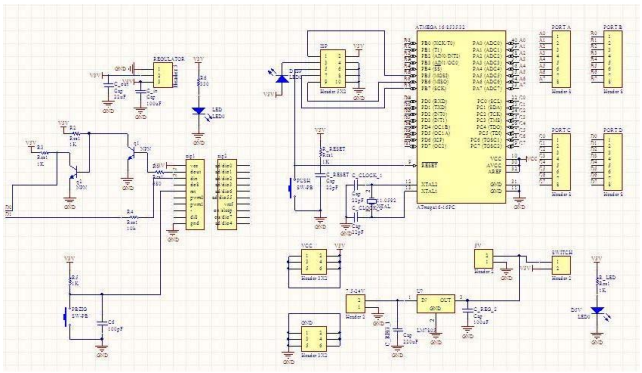

Figure 3.8 Schematic of minimum system and Xbee shield

XBee is configured as a receiver and a transmitter, uses mesh topology of ZigBee protocol. Each XBee address must be set for the configuration. This address includes the parameter PAN ID (Personal Area Network ID), SH (Serial Number High), SL (Serial Number Low), DH (Destination address High), DL (Destination Low). In order to communicate in a mesh topology, XBee must be set first. In this research there are 5 XBees which be set to 3 routers, 1 end device and 1 coordinator. Then the following settings with the XBee mesh topology are applied:

- PAN ID parameter value = Value PAN coordinator all Router ID and Device End
- SH coordinator parameter value = DH all Router and End Device
- The value of the parameter SL coordinator = DL all Router and End Device

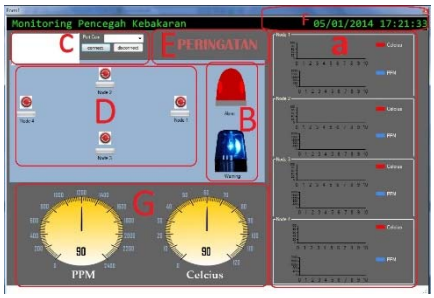

Figure 3.9 Display of GUI

IV. TESTING AND ANALYSIS

The following is testing result of this experiment

Table 4.1 Testing of LM35

No	Range (cm)	Temperature on sensor (celcius)	Temperature on thermometer (celcius)	Error (celcius)
1	10	105	104	1
2	15	86	88	2
3	20	54	55	1
4	25	51	52	1
5	30	48	50	2
6	35	47	47	0
7	40	45	46	1
8	45	45	46	1
9	50	45	47	2
10	55	47	48	1
11	60	48	50	2
Rata-rata				1,3

Figure 4.1 Reading of MQ-7 sensor

According to the test results of MQ-7 sensor, it is shown that it is able to retrieve data of ADC and convert it to the form of units of ppm.

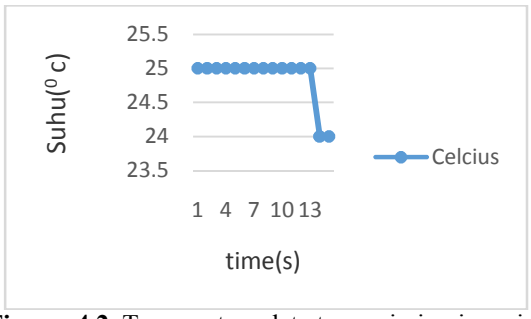

Figure 4.2 Temperature data transmission in serial

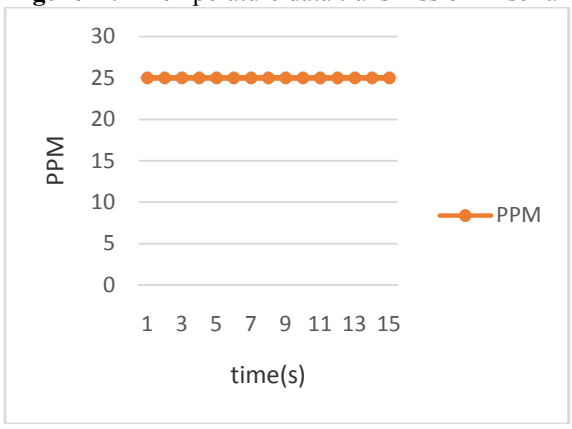

Figure 4.3 PPM data transmission in serial

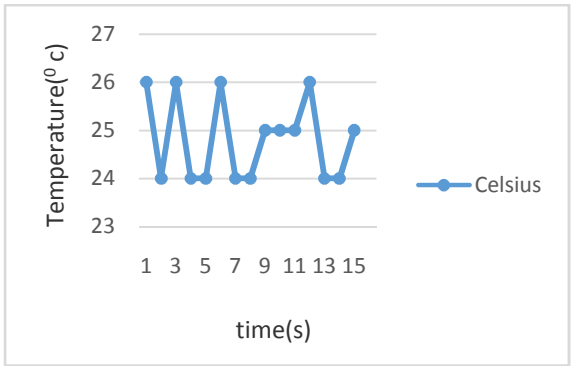

Figure 4.4 Temperature data transmission in wireless

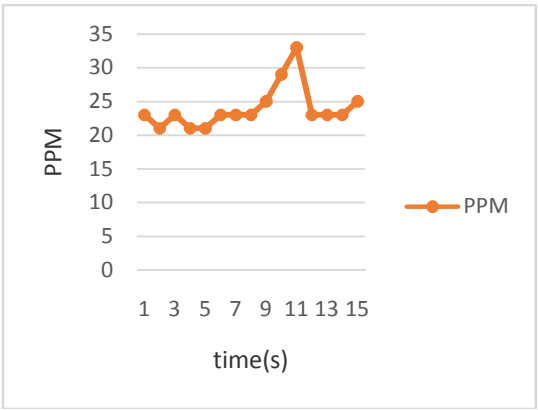

Figure 4.5 PPM data transmission in wireless

Range testing of Zigbee at indoor and outdoor is displayed below

Table 4.2 Range testing at indoor

Range (meter)	Data
1	Received
5	Received
10	Received
15	Received
20	Received
25	Received
27	Received
28	No

Table 4.3 Range testing at outdoor

Range (meter)	Data
1	Received
10	Received
20	Received
30	Received
40	Received
50	Received
60	Received
70	Received
80	Received
90	Received
100	Received
103	No

Testing of system performance includes error testing in the system and time delay recovery. In this test, all the nodes activate nodes 2,3 and 4 placed in an open space whereas the nodes 2 and 3 are placed side by side between node 1 and node 4. Coordinator node is placed in the room but adjacent to node 1 while node 4 is located away from the coordinator, and not connected. The test is performed in a confined space.

Table 4.4 Error Testing

No	Time(min)	Real Node				*Node* on GUI				Information
		1	2	3	4	1	2	3	4	
1	0	ON	ON	ON	ON	ON	ON	ON	ON	OK
2	0,5	ON	OFF	ON	ON	OFF	OFF	ON	ON	*ERROR*
3	1	ON	OFF	ON	ON	ON	OFF	ON	ON	OK
4	1,5	ON	ON	ON	ON	ON	ON	ON	ON	OK
5	2	ON	ON	ON	ON	ON	ON	ON	ON	OK
6	2,5	ON	ON	OFF	ON	ON	ON	OFF	OFF	*ERROR**
7	3	ON	ON	OFF	ON	ON	ON	OFF	ON	OK
8	3,5	ON	ON	ON	ON	ON	ON	ON	ON	OK
9	4	ON	ON	ON	ON	OFF	ON	ON	ON	*ERROR*
10	4,5	ON	OFF	ON	ON	ON	OFF	ON	ON	OK
11	5	ON	OFF	ON	ON	ON	OFF	ON	ON	OK
12	5,5	ON	ON	ON	ON	ON	ON	ON	ON	OK
13	6	ON	ON	ON	ON	ON	ON	ON	ON	OK
14	6,5	ON	ON	OFF	ON	ON	ON	OFF	ON	OK
15	7	ON	ON	OFF	ON	ON	ON	OFF	ON	OK
16	7,5	ON	ON	ON	ON	ON	ON	ON	OFF	*ERROR*
17	8	ON	ON	ON	ON	ON	ON	ON	ON	OK
18	8,5	ON	OFF	ON	ON	ON	OFF	ON	OFF	*ERROR**
19	9	ON	OFF	ON	ON	ON	OFF	ON	ON	OK
20	9,5	ON	ON	ON	ON	ON	ON	ON	OFF	*ERROR*
21	10	ON	ON	ON	ON	ON	ON	ON	ON	OK

Information :

ERROR : *Error* on GUI because error on reading data

*ERROR** : *Error* because *delay time recovery*

It is shown that, serial data transmission more stable than wireless data transmission.

This is due to the influence of the channel (medium) in the wireless data transmission

Table 4.5 Time delay recovery

Test	Time Displacement Route from node 3 to node 2	Time Displacement Route from node 2 to node 3
1	38s	45s
2	19s	18s
3	20s	21s
4	22s	19s
5	21s	24s
Average	24s	25,5s

V. CONCLUSION

This paper presents the design of wireless sensor network for fire detection. Testing and analysis has been done using ZigBee RF module with a mesh topology.

1. Average error of measuring is 1.3 of 11 testing.
2. From the measurement of distance, the system can work stable in 27 meters for indoor measurement and 100 meters of outdoor measurement.
3. Average time delay recovery from 3^{th} node to 2^{th} is 24 s and from 2^{th} node to 3^{th} node is 25.5 s.

The video of the measurement and testing can be downloaded from the link:
http://www.youtube.com/watch?v=CO7j6UQTO2w&feature=youtu.be

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