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ZigBee and Wifi Network Interface on Wireless Sensor Networks

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***Abstract*—Wireless Sensor Network using many wireless communication protocols, such as Bluetooth, ZigBee, ultra wideband, and wifi. Wifi has the advantages of high data rate and long range distances, but it requires a great power. While ZigBee has the advantages that it uses less power, but the resulting low data rate and short range distances. With respective these advantages and disadvantages, this paper make interface between ZigBee and wifi communication standards. Data is transmitted by the ZigBee Transceiver then its received and processed by ZigBee and wifi interface. The result of data conversion then transmitted wirelessly to the wifi transceiver, and it will be displayed on a computer. Wifi transceiver has a dual function, receive data and also send the data back to the ZigBee transceiver to display on LCD through the interface. ZigBee and wifi interface is working to convert the data from TCP/IP protocol into ZigBee protocol and applies vice versa. The system can communicate properly when the baud rate is 9600bps.**

Keywords—zigbee; wifi; interface; monitoring; serial data

I. INTRODUCTION

Wireless Sensor Network using many wireless communication protocols, such as Bluetooth [1], ZigBee, UWB (ultra wideband), and wifi[2]. Each protocol has its own characteristics. UWB is designed for low-power, short-range and high speed data rate. Operational range for UWB can reach 10 meters based on the IEEE 802.15.3 standard[3]. Wifi is based on the IEEE 802.11 specification. The data rate can reach 11 Mbps with distances up to 100 meters, but it needs a great power[4]. ZigBee is a technology with low data rate, low cost, and use small power. ZigBee is IEEE 802.15.4 standard. ZigBee data rates can reach 250kbps and the distance range is 10m - 70m.[5]

Wifi has the advantages of high data rate and long range transmit distances, but it requires a great power that is equal to 400mA on standby operation. While ZigBee has the advantages that it uses less power that is equal to 30mA during standby mode, but zigbee only supports low data rate and short range transmit distances. With respective advantages and disadvantages are owned by these both standard communication, the researchers tried to combine the ZigBee communication standard with wifi communication standards in a telemonitoring system based on wireless networks. ZigBee data packet structure can be seen in Figure 1.

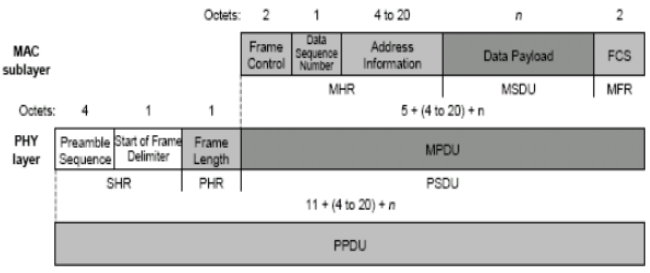

Figure 1. Structure of zigbee data packets [6]

IEEE 802.15.4 standard defines that MAC layer has 4 basic frame: beacon frame, data frame, acknowledgment, and command frames. Beacon frame is used by a coordinator to transmit beacons. Data frame is used to store all data sent. Acknowledgment frame is used to confirm that it has successfully received the data that had just passed, and MAC command frame is used to set up and configure the client.

The PHY layer consists of 32 bits preamble which serves to synchronize the system. Start of frame has a size of 8 bits which serves as a marker of the end of the preamble. Frame length with the size of 8 bits which serves to explain the length of the PHY service data unit (PSDU), and MPOU with size <127 bytes that serves to handle and manage data received from the previous layer.[7]

The structure of the wifi (802.11) data packets consists of application layer protocol that is used to provide the access to TCP/IP services. These protocols include the dynamic host configuration protocol (DHCP), domain name system (DNS), and hypertext transfer protocol (HTTP). Inter-host communication layer has function to make the session connection is connection-oriented or connectionless broadcast. Protocols at this layer is the Transmission Control Protocol (TCP) and User Datagram Protocol (UDP).

Internetwork layer protocol is responsible for routing and encapsulation of network data packets into IP packets. Protocols that work at this layer is the Internet Protocol (IP), Address Resolution Protocol (ARP), Internet Control Message

Protocol (ICMP), and Internet Group Management Protocol (IGMP).[7,8]

Network interface layer protocol is responsible for laying the network frames over the network media used. TCP/IP can work with many transport technologies, ranging from transport technologies in the LAN (such as Ethernet and Token Ring), MAN and WAN (such as dial-up modems that run on top of the Public Switched Telephone Network (PSTN), Integrated Services Digital network (ISDN), and Asynchronous Transfer Mode (ATM)). The wifi data packet structure can be seen in figure 2.

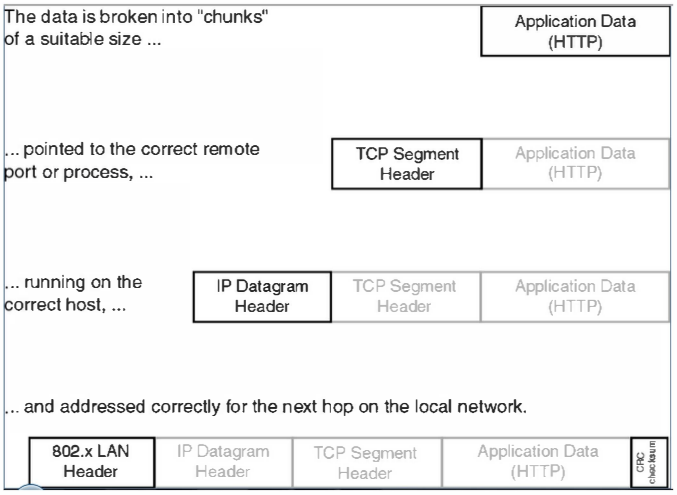

Figure 2. Structure of wifi data packets [8]

II. ZIGBEE AND WIFI INTERFACE

The design of ZigBee and wifi networks interface for telemonitoring is divided into three sections (figure 3). The first part is the design of ZigBee Transceiver (ZB-TRx), the second part is the design of ZigBee and wifi interface (Z2W), and the third part is the design of wifi transceiver (W-TRx).

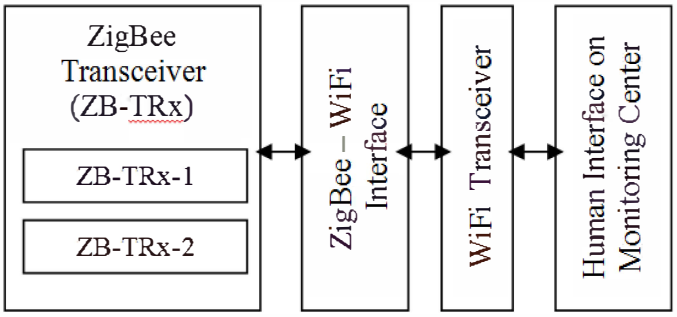

Figure 3. Block diagram of zigbee and wifi networks interface for telemonitoring

Data is transmitted by the ZB-TRx then its received and processed by Z2W. The result of data conversion then transmitted wirelessly to the W-TRx, and it will be displayed on a computer using a terminal device program. Wifi transceiver has a dual function, receive data and also send the data back to the ZigBee transceiver to display on LCD through the Z2W. ZigBee and wifi interface is working to convert the data from TCP/IP protocol into ZigBee protocol and applies vice versa. Block diagram of the overall system design can be seen in Figure 3.

2.1 ZigBee Transceiver

ZigBee transceiver consists of a microcontroller ATMega8, humidity sensor, XBee PRO series, and the LCD (figure 4). A microcontroller is a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications. Voltage source in the ZigBee transmitter using an adapter with a voltage of 9-12 volts. Due to the microcontroller requires a 5 volt power supply, the voltage source is derived using LM7805 regulator circuit and combined with TIP31C so that the current is greater (3A). XBee PRO works in the voltage range from 2.8 to 3.4 volts, so the voltage regulator circuit LM317 necessary to make the supply voltage lower. ATMega8 read the data from the humidity sensor (figure 5) using analog to digital port and forward this data into the XBee PRO to be delivered wirelessly.

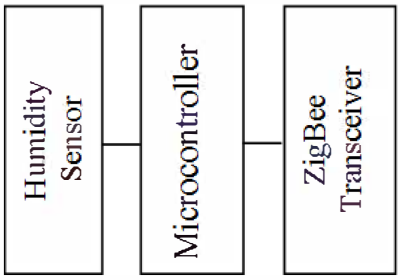

Figure 4. Zigbee transceiver

XBee PRO is used as the sender of the data wirelessly from the transmitter to the receiver using ZigBee protocol communication. XBee PRO works on 3.3 V_{DC} voltage levels, while the microcontroller working at 5 V_{DC} voltage level, so it is needed an adjustment transmission and reception path of

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data from the microcontroller to the XBee PRO. It required a 3.3 V zener diode as a voltage level cutting (voltage driver). It also installed an LED that serves as an indicator of the status of XBee PRO. LED will light up if the XBee PRO is already active. D_{OUT} pin on the XBee PRO is connected to the Rx pin microcontroller as data delivery path from the XBee to the micro, while the D_{IN} pin on the XBee connected to the Tx pin on the micro as data delivery path from the micro to the Xbee (figure 6).

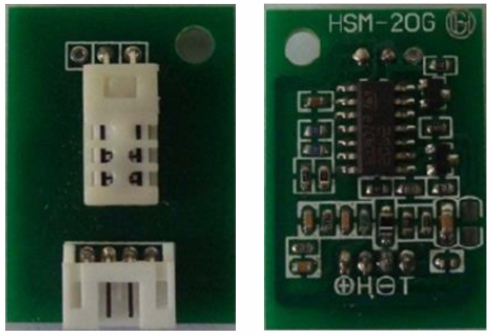

Figure 5. Humidity sensor

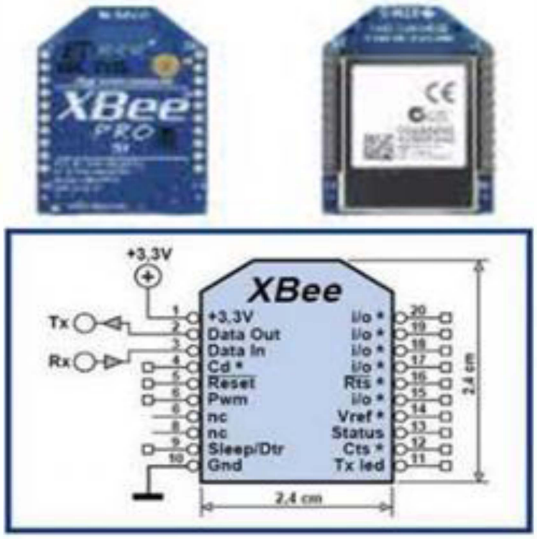

Figure 6. Xbee PRO transmitter

Before XBee PRO is used, the XBee PRO needs to be configured first in order to communicate with each other. Configuration mode on this device is transparent mode (AT) with 16-bit addressing system. This system using 3 pieces of XBee PRO. XBee PRO configuration use the X-CTU software that is specifically provided by the XBee manufacturers. XBee PRO configurations used are listed in Table 1.[9]

To be able to communicate with each other, XBee PRO must have same network ID (PAN ID). Baud rate on the XBee PRO adjusted the baud rate on the microcontroller that is equal to 9600 bps.

Table 1. Configuration of XBee PRO

No	Parameter	*XBEE PRO1*	*XBEE PRO0*
1	*PAN ID*	2013	2013
2	*DL (Destination Address Low)*	0	1
3	*MY (Source Address)*	1	0
4	*BD (Baud Rate)*	9600	9600

The flow diagram of ZigBee Transceiver can be saw in this figure bellow

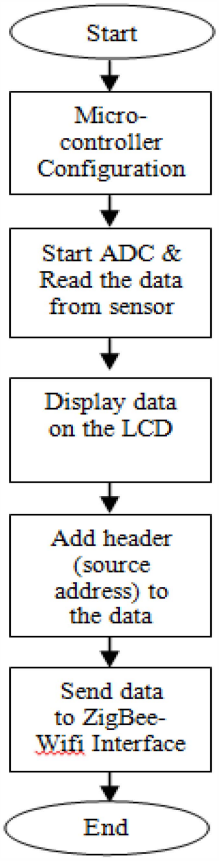

Figure 7. Flow chart of ZigBee Transceiver

2.2 ZigBee to WiFi Interface

ZigBee-wifi interface (figure 8) consists of several parts: XBee PRO series, wifi transceiver, serial interface circuit port (DB9), and a power supply. Wifi transceiver using WIZnet 110SR (figure 9). MAX232 IC is used as a voltage level converter between WIZnet and XBee PRO. Because the COM port on WIZnet 110SR can not be directly connected to the microcontroller, so it is required to serve the driver's lane change signal voltage RS-232 to TTL voltage levels in order to be accepted by the AVR microcontroller.

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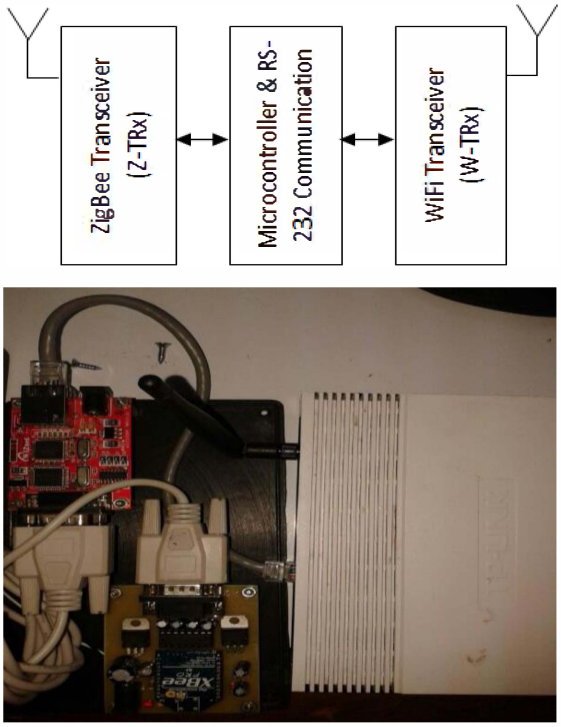
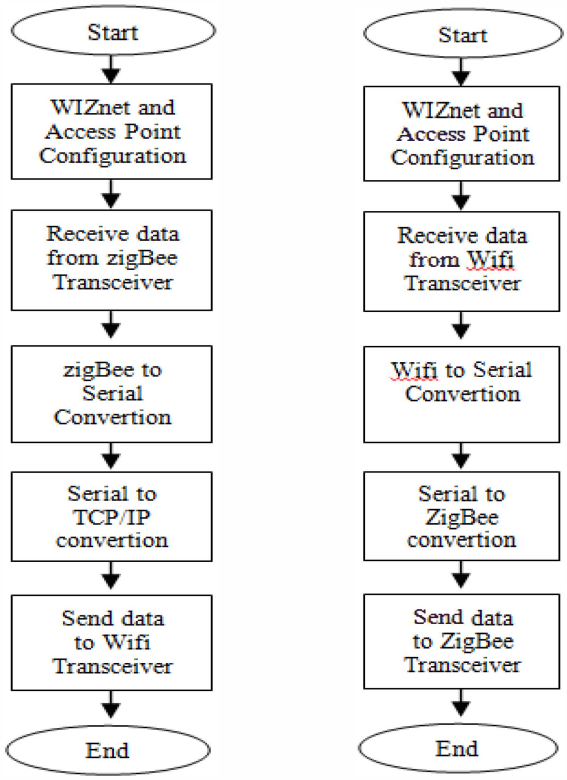


Figure 8. Zigbee to Wifi interface

Figure 9. Board *WIZnet 110SR*

WIZnet configuration serves as the synchronization between the microcontroller and WIZnet. In order to make the network work properly, the important thing to do are: setting IP WIZnet, a port on the network, speed, data bits, parity, stop bits and flow [10]. In this study serves to connect the access point gateway module WIZnet 110SR with computers, to make the network can work well we need some configuration of the IP address of the access point. This configuration is intended that the access point's IP address, IP address WIZnet 110SR, and the computer's IP address into a network.

Basic programming language with BASCOM-AVR software is used in this study, while the software interface to display data on a computer using a terminal device which program is the default program of WIZnet 110SR. The flowchart of zigbee-wifi interface when receiving data from the ZigBee Transceiver and send data to the Wi-Fi transceiver can be seen in Figure 10.a, and flow diagram ZigBee-wifi interface when receiving data from the Wi-Fi transceiver and sends the data to the ZigBee transceiver can be seen in Figure 10.b.



(a) (b)

Figure 10. Flow diagram of the interface (a) ZigBee to wifi and (b) the wifi to ZigBee

III. RESULT AND DISCUSSION

The test determine the capabilities and reliability of the system that has been created. Testing was conducted on the testing of the power supply circuit, testing of data connections from the access point to a computer, sending ZigBee distance, and distance from the access point to the delivery of the computer. Testing the power supply circuit is done by measuring the output voltage (Vout) of the series that has been made. Minimum system of ATMega8 uses 5 volt power supply. While the 3.3 volt power supply is used to supply the XBee PRO transceiver. The resulting voltage are between 4.95 - 5.03 volts and 3.04 - 3.04 volts.

Testing of data connection from the computer to the access point aimed to determine the stability of data transmission from the access point to a computer or vice versa. This testing is done the experiment data transmission up to 12 hours. Based on the results of the testing that has been done, it was concluded that all devices on the system is on and functioning properly. Testing of ZigBee range transmission is done to determine the maximum distance ZigBee data transmission. The maximum data transmission distance is 25 meters. Testing data transmission distance from the access point to a computer

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is done indoors to determine the maximum distance data transmission between the access point and the computer. From the test results obtained maximum delivery distance is only 69 meters. This is not in accordance with the datasheet information which indicates the access point shipments reached a maximum distance of 100 meters . This is because the signal of access point is blocked by a wall so the data can not be transmitted maximum like indicated on the datasheet.

Humidity sensor (HSM 20-G) test is done by comparing the value of the humidity sensor readings with hygrometer readings. To get the value of different humidity, the test is done at different times and locations. Tests are carried out since noon, night and morning, while test locations are indoor and outdoor areas. The average error percentage of sensor readings are 1.54% at sensor-1 and 3.53% at sensor-2. The test results of humidity sensor can be seen in table 2 and figure 11.

Table 2. Results of humidity sensor testing

Humidity by Sensor (%)		Higrometer (%)
Sensor-1	Sensor-2	
55.89	60.76	58
59.42	62.52	60
61.93	64.80	62
67.67	69.11	66
71.60	73.54	70
72.33	74.52	72

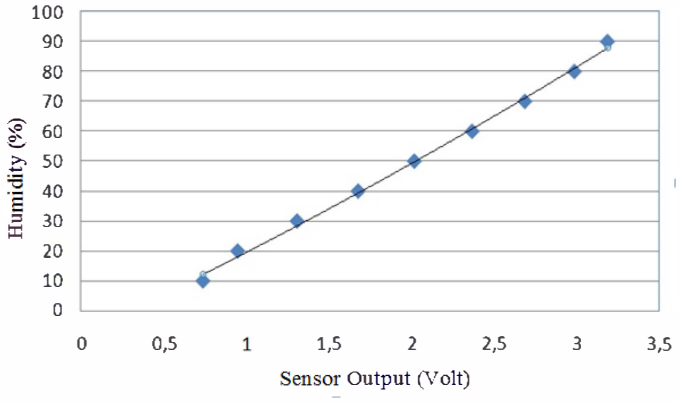

Figure 11. Relationship between sensor output and humidity

When baudrate be set at 4800, the data sent from the ZigBee transceiver can be received by the computer, but the data received does not match the data sent. While the data sent from the wifi transceiver can not be accepted by the ZigBee transceiver. During the experiments, when baudrate set at 9600 we can see that the data sent in accordance with the data received, from both of ZigBee transceiver and wifi transceiver. While baudrate at 19200 bps, data transmission has an error.

One of the applications of ZigBee and WiFi interface can be saw on figure 12. Wireless sensor network using zigbee protocol consist many nodes, they collect the datas from the environtment, the data collect at the head node. Then, it convert from zigbee protocol to wifi protocol in ZigBee and WiFi interface. Finally, the data are sent from the monitoring area to monitoring center using wifi point to point communication.

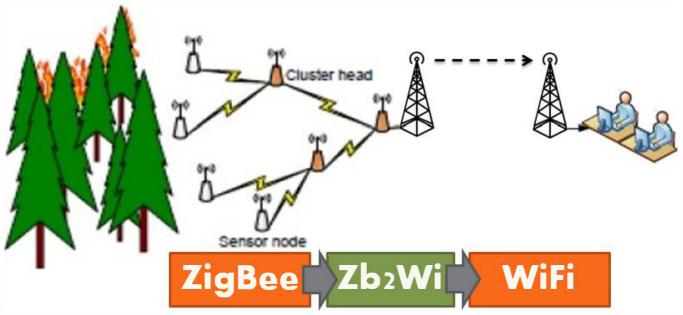

Figure 12. One of the applications of ZigBee and WiFi interface

IV. CONCLUSION

From the testing that has been done, it can be concluded as follows. Network which has been designed is work well where data sent use the ZigBee standard is acceptable to the Wi-Fi network, and vice versa. Humidity sensors have 3.8% error. Distance communication in the process of sending data from the computer to the access point is 68m. The system can communicate with both the current value of the baud rate is 9600.

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