WIRELESS SENSOR NETWORK DESIGN AND IMPLEMENTATION WITH RF XBEE MODULES AND PHOTOTRANSISTOR SENSORS TO MEASURE THE LEVELS OF WATER TURBIDITY

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Abstrak

Kekeruhan air sebagai parameter penting yang menentukan kualitas air memegang peranan penting bagi setiap mahkluk hidup dan karenanya cukup penting untuk diukur. Besaran kekeruhan ditentukan oleh suatu nilai yang disebut Nephelometer Turbidity Unit (NTU). Semakin tinggi nilai NTU, maka air akan semakin keruh dan sangat berpengaruh terhadap kualitas air. Turbidimeter umum digunakan untuk mengukur kekeruhan air dengan keakuratan tinggi namun memiliki harga yang cukup mahal dipasaran (US$600). Dengan kemajuan teknologi, hasil keluaran sensor dapat diukur secara nirkabel dari jarak jauh dengan menggunakan Wireless Sensor Network (WSN). Tugas akhir ini bertujuan untuk membuat turbidimeter berharga relatif murah dibandingkan turbidimeter dipasaran dengan fitur t ambahan WSN. WSN yang dibangun untuk mengukur kekeruhan air terdiri dari turbidimeter yang dibuat dari LED inframerah dan fototransistor. Modul Radio XBee digunakan sebagai alat untuk mentransmisikan dan menerima hasil pengukuran sensor secara nirkabel. Li brary XBee digunakan pada program Arduino untuk mendefinisikan format frame paket data dan mekanisme pemaketan - perakitan data. Program pemantau dalam bentuk GUI terletak pada node koordinator untuk mengukur tingkat kekeruhan air. Turbidimeter yang dibuat m emiliki daerah pengukuran 0 - 1289.3 NTU untuk end node A dan 0 - 1415.7 NTU untuk end node B. Error terkecil terjadi pada daerah pengukuran 119 – 350 NTU untuk masing - masing turbidimeter, sedangkan galat dapat mencapai nilai 700% pada pengukuran NTU rendah (0 - 100 NTU). Hal ini mengindikasikan konfigurasi turbidimeter yang tidak sesuai untuk pengukuran NTU dalam skala rendah (dibawah 100 NTU). Galat rata - rata turbidimeter pada skala pengukuran 119 – 350 NTU unuk end node A adalah 3.56% sedangkan untuk node B ad alah 5.9%. Perbedaan daerah pengukuran NTU pada masing - masing end node disebabkan oleh perbedaan jarak yang ditempuh oleh cahaya LED inframerah yang berdampak kepada intensitas cahaya yang diterima oleh fotodetektor di masing - masing end node . Hubungan inte nsitas pada node A dan node B dapat ditulis sebagai ' () ll BA I e I dimana l ’ adalah jarak yang ditempuh oleh cahaya LED inframerah di node B dan l adalah jarak yang ditempuh oleh cahaya LED inframerah di node A. Pengaturan posisi dari LED infr amerah dan fototransistor berpengaruh kepada daerah hasil pengukuran NTU. Intensitas yang lebih besar pada node B memperbesar daerah pengukuran NTU akan tetapi juga menurunkan akurasi dari sensor. Performa WSN di ruang semi tertutup - sempit dengan dimensi 6 0x5x20 meter 3 memberikan jarak pengukuran maksimal sejauh 40 meter untuk masing - masing end node dengan nilai RSSI - 87 dBm untuk end node A dan - 86 dBm untuk end node B. Dalam kondisi ruangan tertutup - sempit yang memiliki dimensi 100x5x5 meter 3 , dicapai jarak pengkuran maksimum 75 meter untuk masing - masing end node pada nilai RSSI - 80 dBm. Diperkecilnya dimensi ruangan menyebabkan sedikit peningkatan pada jarak maksimum yang dapat diraih oleh end node terhadap coordinator node namun menyebabkan n ilai RSSI yang lebih fluktuatif dikarenakan berbagai fenomena interferensi gelombang radio seperti perbedaan jarak yang ditempuh oleh gelombang radio dan efek multipath fading .

Kata Kunci : WSN, RF XBee, fototransistor, turbidimeter, NTU

Abstract

Turbidity as an important parameter to determine the quality of water holds important role for every living creature and therefore worth to be measured. The unit to measure turbidity is called Nephelometer Turbidity Unit (NTU). The higher NTU, the more tu rbid the body water becomes and therefore affects the water quality. Turbidimeters are commonly used to measure various liquid turbidity with high accuracy but come in a high price (US$600). By the advance of technology, any sensors could be measured wirel essly from the distance by using Wireless Sensor Network (WSN). This final project aims to build a relatively low - cost turbidimeters with a reasonable accuracy that come with additional WSN feature. The constructed WSN system for measuring water turbidity consisted of two turbidimeters at its end nodes created from IR LED and phototransistors and one coordinator node at the base station. The RF XBee modules are used as device s to transmit and receive data wirelessly. A custom XBee library is used to define data packets frame format and data packetization - assembling mechanism. A monitoring program in GUI form is located at coordinator node to measure the levels of water turbidity remotely . The constructed turbidimeter in end node has a measuring range of 0 - 1289.3 NTU for end node A and 0 - 1415.7 NTU for end node B.The smallest error variation occurs in range of 119 – 350 NTU for both turbidimeters while the errors could as high as 700% in low NTU range measurement (0 - 100 NTU). This indicates that the configur ation of turbidimeter is not suitable for low NTU measurement (below 100 NTU). The average error percentage for turbidimeter within range of 119 – 350 NTU for end node A is 3. 56 % while in node B is 5 . 9 %. The difference of NTU measuring range in each end no de is caused by different path distance travelled by IR lights therefore affects the intensity value preceived by both sensors. The intensity relationship between node A and node B can be stated as ' () ll BA I e I where l ’ is the distance travelled by IR light in node B and l is the distance travelled by IR light in node A. The positioning of IR LED and phototransistor is significantly affect the readings and NTU measurement range. Larger intensity acquired in node B yield s to more NTU range but also decreases its measurement accuracy significantly. The WSN performance in a semi confined space environment of 60x5x20 meter 3 yields a maximum range of 40 meters for both end nodes at RSSI value of - 87 dBm for end node A and - 8 6 dBm for end node B. In a confined space environment of 100x5x5 meter 3 , a maximum range of 75 meters for both end nodes at - 80 dBm of RSSI value is achieved. More confined space slightly increases the RF XBee range however the RSSI value will be more fluc tuative due to radio wave interferences phenomena such as variation of distance travelled by radio signals and various multipath fading effects.

Keywords : WSN, RF XBee, phototransistor, turbidimeter, NTU

CHAPTER I

INTRODUCTION

1.1. Background

Water, as a primary of human needs takes an urgent role to support everyday activities. Water has an important parameter to measure its quality, that is turbdity. The turbidity of water is caused by suspended solid particles comes either from organic or anorganic subtances. Turbid water has long been correlated to various dangerous diseases such as dysentry, cholera, and many more. In indonesia many institutions that conducting water processing such as PDAM always take a great care in measuring water turbidity levels. To make water turbidity measurement more convenient and easier, the system which could monitor the water turbidity levels remotely, continously and sotore its measurement results in a database is needed. The Wireless Sensor Network (WSN) system could make that possible. The water turbidity sensors could also be made by a simple electronics circuitry and relatively cheap component price so the tools to measure water turbidity (turbidimeter) could be made cheaper than the available commercial turbidimeters which cost more than Rp5.000.000,00 (U.S. $ 600) in the market.

WSN is already implemented pervasively in many sectors to measure various physical paarmeters such as voltages, temperatures, vibrations, and many more parameters because of its robustness and easiness to implement the network installation. Furthermore, the power needed to run WSN is relatively small so it will bring to an efficient, effective power-use electronics system. WSN with XBee Radio Frequency (RF) modules that implement IEEE 802.15.4 protocol will be used as a transciever that could send and receive a stream of data packet which contain sensors reading output and its RSSI values and display it at a monitoring center using Laptop through Graphical User Interface (GUI) designed Bay the help of Visual Basic Program. Sensors which could measure the water turbidity levels are made of Phototransistors as photodetector and Infrared Light Emitting Diode (LED) as the source of light.

This final project is expected to be able to create WSN system with sensors which coud measure water turbidity levels with good performance and relatively low cost compared to the available commercial turbidimeter . Besides that, it is expected that the optical phenomena which cause the water or any liquid to become turbid is explained in a satisfactory way.

1.2. Problem Statement

The problems which are discussed in this final project include :

1. How to design and implement WSN system by using RF XBee modules and phototransistor-based sensors to perform water turbidity monitoring ?
2. How to decide, design and implement sensor modules so it could measure water turbidity levels ?
3. How to design experiment scenarios to measure the water turbidity level ?
4. How to wirelessly communicate data from sensors with its RSSI value to the monitor station so it could be perceived in a GUI form and stored in a database ?
5. How to qualitatively explain optical phenomena that caused water or any liquid to become turbid ?

1.3. Purpose

The purposes of this final project are :

1. To design WSN system by using XBee RF modules and photoransistor-based sensors to detect water turbidity and represent it in monitoring base in graphical interpretation and save the sensors readings in database so that it could be taken anytime.
2. To analyze the performance of created turbidimeters.
3. To analyze the created WSN system by conducting measurement in various distances and in two different indoor environment conditions.

1.4. Scope of Problems

There are some restrictions to this final project :

1. WSN system is implemented by using RF XBee modules model XB24-AWI-001 with wire antennas.
2. This final project does not discuss about network security systems and only briefly explains the power usage of WSN system.

3. WSN system uses star topology and single hop communication based on IEEE 802.15.4 communication protocol.
4. WSN system uses two RF XBee modules. One acts as a node coordinator and two act as node sensors.
5. There are two experiments that will be performed to measure WSN performance, experiment in the semi confined and confined indoor environment.
6. Solution from liquid soap and water mixture is used to made standard turbidity solution.
7. Monitoring system is created by Visual Basic 2010 and a laptop with specification of : Windows 7 Professional Operating System, intel Core i5 processor and 4 GB of RAMs.

1.5. Research Methodology

1. Literature study

   In this phase, literature based study will be conducted to support research experimentations and to explain the data that resulted from it.
2. System and design analysis

   Design and analysis to the system will be performed to set suitable WSN system specifications.
3. Implementation

   After specifications are already at set, the implementation process is on the way to implement the design which is made before.
4. System testing through experiments

   The realization of design will be tested by experiments in order to determine overall WSN system performance.
5. Analysis

   The analysis is conducted to confirm whether the designed system follows every theory explained in literatures and able to measure water turbdity reliably.
6. Report Making

   In this final phase, every data regarding this research will be summarized in one book so that it could become a reference for people who interested in WSN system.

1.6. Writing Systematics

This final project book comprises of several chapters that assembled in this way :

Chapter I INTRODUCTION

This chapter explains background, problem statement, purpose, scope of problem, research methodology, writing systematics, and plan of scheduling.

Chapter II THEORY

This chapter explains theories that are made as a foundation to support research literature and to explain experiments outcome.

Chapter III SYSTEM DESIGN AND IMPLEMENTATION

This chapter explains WSN system design and implementation.

Chapter IV EXPERIMENT RESULTS AND ANALYSIS

This chapter explains experiment results.

Chapter V SUMMARIES AND FURTHER RECOMMENDATION

This final chapter explains the summary of research and further recommendation to improve WSN system performance in the future.

CHAPTER V

SUMMARIES AND RECOMMENDATIONS

5.1. Summaries

1. The constructed turbidimeter in end node has a measuring range of 0-1289.3 NTU for end node A and 0-1415.7 NTU for end node B.
2. The smallest error variation occurs in range of 119 – 350 NTU for both turbidimeters while the errors could as high as 700% in low NTU range measurement (0-100 NTU). This indicates that the configuration of turbidimeter is not suitable for low NTU measurement (below 100 NTU). The average error percentage for turbidimeter within range of 119 – 350 NTU for end node A is 3.49% while in node B is 6.14%. The difference of NTU measuring range in each end node is caused by different path distance travelled by IR lights therefore affects the intensity value preceived by both sensors. The intensity relationship between node A and node B can be stated as $I_B = e^{(l' - l)} I_A$ where *l*' is the distance travelled by IR light in node B and *l* is the distance travelled by IR light in node A. The positioning of IR LED and phototransistor is significantly affect the readings and NTU measurement range. . Larger intensity acquired in node B yields to more NTU range but also decreases its measurement accuracy significantly.
3. The WSN performance in a semi confined space environment of 60x5x20 meter^3 yields a maximum range of 40 meters for both end nodes at RSSI value of -87 dBm for end node A and -86 dBm for end node B. In a confined space environment of 100x5x5 meter^3, a maximum range of 75 meters for both end nodes at -80 dBm of RSSI value is achieved. More confined space slightly increases the RF XBee range however the RSSI value will be more fluctuative due to radio wave interferences phenomena such as variation of distance travelled by radio signals and multipath fading effects .

5.2. Recommendations

1. For further development, the system should be integrated with internet networks so the sensors readings could be attained and accessed everywhere and anytime.
2. To increase turbidimeter performance in terms of accuracy and NTU range measurement, IR LEDs with peak wavelength closest to phototransistor's maximum relative sensitivity and additional phototransistor located perpendicular to light source should be used.
3. The WSN operational time can be extended further by the use of batteries with larger power ratings and by activating the sleep mode in end node while not in use.

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