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On the Wireless Sensor Network for Medical Instruments Monitoring System

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Abstract – Infusion is very useful in the field of health one of which is to increase fluid in patients, especially in patients who cannot consume meals directly. Therefore, the intravenous infusion into the patient cannot be delayed because the delay of intravenous infusion is very fatal for the patient being treated. To overcome this problem, it is necessary to create a tool that can monitor the use of infusion to avoid delays, by showing how much residual fluid contained in the infusion that is being installed in a patient. To detect the infusion droplets used by the photo diode sensor, the infrared sensor and then the sensor readings are sent to the ZigBee wireless sensor network (WSN) and look directly at the 2x16 LCD monitor, which features the following excellent features: It adopts a high performance chip price ratio RS232-USB pre terminal, integrated into circuit board, take up a lot of space. System has low power benefits and strong anti-interference, can work without special requirements in the hospital environment ZigBee technology has been used to achieve real time control of multiple points of infusion, convenient network construction. This system has good control precision and can adjust infusion parameters.

Index Term - Infusion, Monitoring, Zigbee RS232-USB. WSN, Droplets count, LCD, Sensors

1 Introduction

The rapid development of wireless technology in recent they were led to the development of wireless telecommunication devices. Starting from communication devices that involve households, hospital offices to communication devices related to the military. One of the wireless technologies that are being developed with various applications is Wireless Sensor Network (WSN). Wireless Sensor Networks

(WSN) has become a technology that has wide application potential including in terms of environmental monitoring, object searching, scientific estimates and observations, traffic control and more [1]. No exception in the health field, one of the most commonly used medical devices is the infusion, in the current hospital infusion monitoring system, still done manually by medical personnel, to determine the number of drops to be administered to the patient [2]. Infusion is an important part of the world of health one of the use of infusion is for the administration of drugs, food, in certain amounts with appropriate medical intervals into the veins through droplets. During this time to know the condition of infusion in the hospital a medical staff should check to every room patient or wait if there is a call from the inpatient room, it is very risky because if the patient is sleeping or fainted there is certainly no call from patient to medical personnel.

Though the infusion fluids have been discharged this will certainly make the danger to the patient because no fluid that enters the body and the possibility of blood will enter into the infusion tube. Errors in administering intravenous fluids can be detrimental to the patient, also in the event of problems such as blockage or running out of fluids if not treated promptly will be harmful to the patient, change and control of infusion bottles should be properly addressed because delayed replacement of infusion that has been exhausted can be fatal to the patient and result in death [3]. Therefore, a device designed the amount of droplet infusion in patients equipped with remote monitoring system, by adding sensors that can detect how much liquid is still contained in the IV bottle. Delivering data to author computer using ZigBee Wireless Sensor Network (WSN). This certainly makes it easier for medical personnel to work in hospitals because each infusion bottle that has been installed can be monitored on the computer and in the hospital improves the quality of service. Efforts to utilize and modify related algorithm in various fields are also implemented on [10][11][12].

Wireless Sensor Network (WSN) or wireless sensor network is a wireless network consisting of several individual sensor nodes placed in different places to monitor the condition of a place and can interact with the environment by sensing, Controlling A and N communication against parameters-parameters. Physical [4]. In Figure 1. Shows the WSN overview, it can be seen the small sensor nodes are spread in a sensor area. The sensor node has the ability to route data collected to other adjacent nodes. Data transmitted via radio transmission will be forwarded to the BS (Base Station) or sink node, which is the link between the sensor node and the user. Such information can be accessed through various platforms such as internet or satellite connection so allows the user to be able to access in real-time via remote server.

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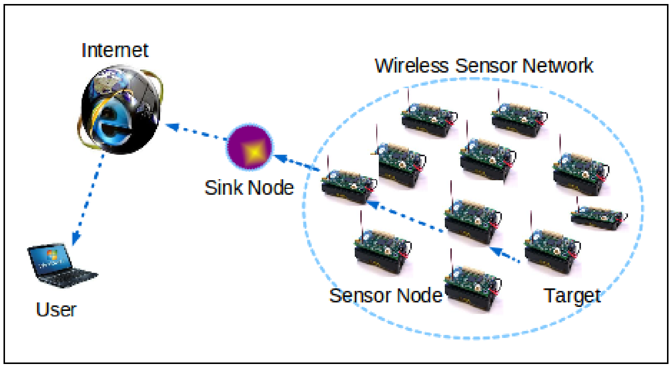

Fig. 1. WSN Architecture

The Xbee series one RF module is designed to operate in the ZigBee protocol at low cost and wireless sensor networks using low power. This module requires low power and can perform reliable data transmission between devices with long distances. This module operates at a frequency of 2.4 GHz. Xbee series two has several models of antennas, one of which is the antenna chip and wire antenna. The antenna chip is a ceramic chip located on the Xbee module board. The shape is smaller. The antenna chip has a cardiodid radiation pattern, which means the signal attenuated in many directions and is best used in a small or too small area [5].

Figure 2. Xbee Series 1 Chip Antenna

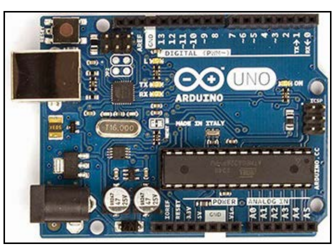

Fig. 5. Arduino Uno Atmega328P

The super-bright LED functions as the sender of light to the line to reflect and read by the photo-diode sensor. The nature of the white color (light surface) that reflects light and the non-reflective black color (dark surface) is used in this application. The picture below is an illustration of the line sensor mechanism [9].

Infrared or can be known as IR LED is one type of LED (Light Emiting Diode) which can emit invisible infrared light. IR LEDs can propagate infrared light when a forward bias voltage is applied to the anode and the cathode because it is made with special materials gallium arsenide (GaAs) then the IR LED can emit infrared light waves.

Fig. 3. IR Led

LCD is a Liquid Crystal Display or electronic device that can be used to display numbers or text. There are two LCD screens that can display numeric and display alphanumeric text [7].

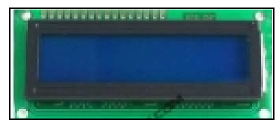

Fig. 4. 16x2 Character LCD

Arduino is an open-source single board micro controller, derived from Wiring platform, designed to ease the use of electronics in various fields. Hardware has an Atmel AVR processor and the software has its own programming language [8].

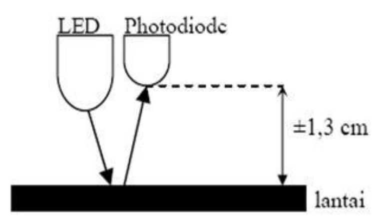

Fig. 6. Illustration of Line Sensor Mechanism

2 RESEARCH METHOD

The research method used is a Research Library supported by conducting hardware experiment. Then, step research flowchart is described in Figure 7.

Sensors receive data in the form of changes in the value of analog light when there are droplets and no droplets. Furthermore analog data is converted into digital data using ADC feature on arduino Uno ATmega328P. Digital data is processed on arduino Uno ATmega328P for classification there are droplets and no droplets. After the data of droplet has been obtained, then the data is converted into units of drops per minute. Data per minute droplets will be displayed on the LCD and there will be a warning when the droplets are unstable and the infusion fluid is exhausted.

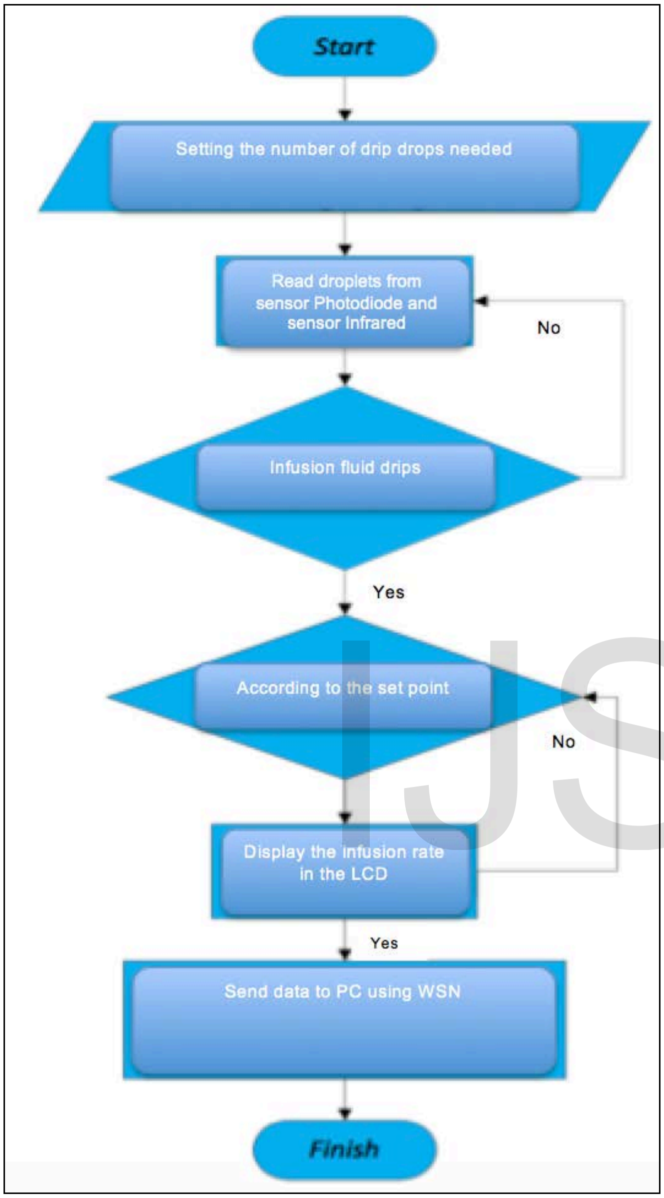

Fig. 7. Step Research Flowchart

3 Results and Analysis

3.1 Designning Hardware and *Program* System

The design of hardware systems and programs on Infusion Medical Monitoring System Based on ZigBee Wireless Sensor Network (WSN), the overall system block diagram created to facilitate the author in doing the design. Figure 8 shows an overview of the system. The block diagram on this system has three main parts namely input, Arduino Uno ATmega328P, and output. In the input section of this system consists of a series of Photodiode, infrared and two button push button sensors. Sensors in this system located in the middle of the drip tube infusion that serves to detect the presence or absence of droplets. The push button 'green' button on this system is used for the OK button and the 'red' key is used for the reset button.

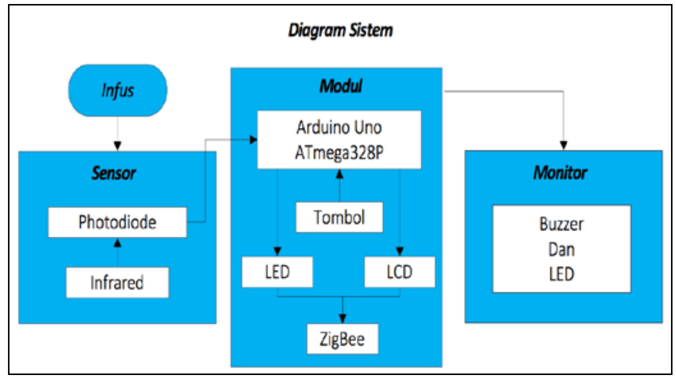

Fig. 8. Diagram of Hardware and Program Design System

In Figure 9, the system will work when infrared sensors and photo-diode detect drip drops. If an infusion drip is not detected then, the arduino Uno ATmega328P will wait for the data when the drip is detected, then the data obtained from the sensor readings will be processed by arduino Uno ATmega328P and will be displayed on the LCD screen. If the ≤50ml infusion volume, the system will send data to the computer PC.

3.2 Designing Hardware

Sensor design on the infusion required sensor casing that can be adapted to the existing infusion form in general. This sensor box is made of a material black plastic with a size of 7.5cm x 5cm and has a half-circle piece as a liaison with the infusion. Use a drip tube material made of plastic so that it can be elastic connected to the sensor box that has been made, making the sensor box can be firmly installed on the infusion. In this sensor box, there is a series of sensors in the form of Infrared and photo-diode.

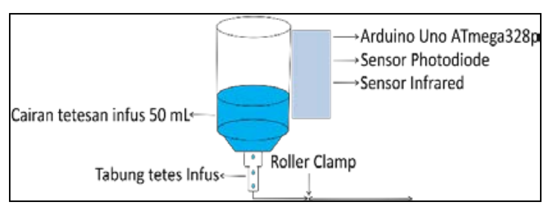

Fig. 12. Design of Infusion Sensor

In Figure 12. Shows the picture to know whether the infusion fluid has been exhausted or not then tested the port voltage that connects the level sensor to the ZigBee port. The data were collected five times for the intravenous fluid condition and so was the case for the infusion fluid. Given the result of level sensor testing when infusion fluid is detected there is. Each test is done under different conditions and times, ie on some tests given when the system has just done 'start up'. In addition, the level of clarity of intravenous fluid samples also varied. Tests conducted to determine the accuracy of the system in monitoring droplets of intravenous fluids using infrared and photodiode sensors. The result of this test is compared with the results of direct visual monitoring based on the parameters contained lactate ringer infusion packing using a macro typeset infusion, the drip factor used is 50ml.

3.3. System Mechanic Design

In Figure 10. The figure on the Box Monitor is designed to be rectangular with a length of 14.5 cm, 9.5 cm wide and 5 cm high. Made of black plastic (Acrylic) for adapter socket, with two buttons that have function for OK, Reset and Switch. The box also comes with 2x16 LCD and three LED indicator lights (green, yellow, and red).

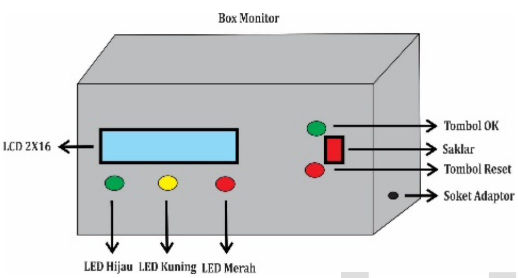

Fig. 10. The Mechanical Design of The System

3.4 Data and Analysis of Research Results

A series of test results and analysis of the research that has been done. The results of the experiment were conducted to see how successful the method was applied, while the analysis conducted by the test result in order to get the conclusion and the suggestion for the next research. In this section the test is focused on finding the maximum outdoor distance and sending data indoors. Outdoors here is a large area inside the building without obstacles, the location indoors with the condition of the infusion device is placed in the patients room with the door open.

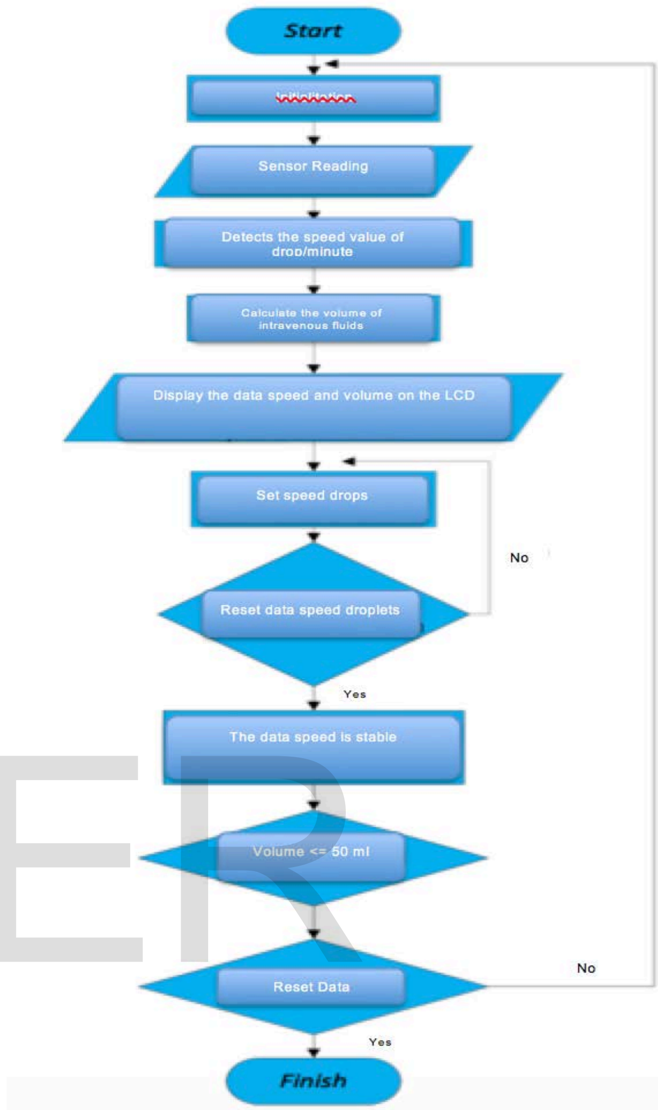

Fig. 9. Flowchart Program Diagram of Infusion System

3.5 Testing of Infrared and Diode Sensors

By doing the calculation then the LCD can be displayed number of droplets per minute. The sensor outputs high output when it does not detect infusion droplets, which means that infrared light is received directly by the photo-diode.

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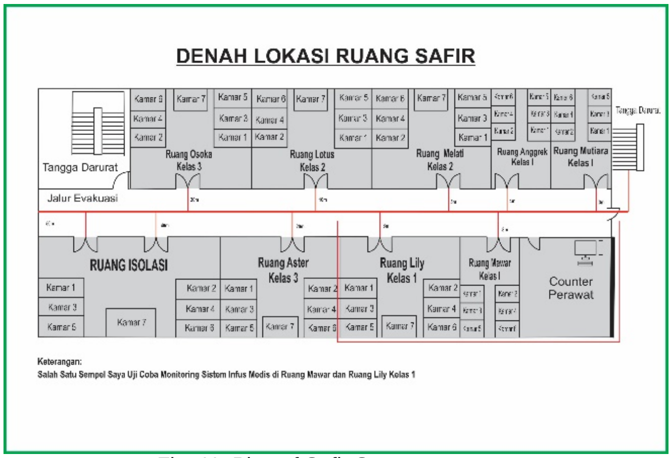

Fig. 11. Plan of Safir Space

The results of medical infusion monitoring system monitoring based on ZigBee WSN are as follows:

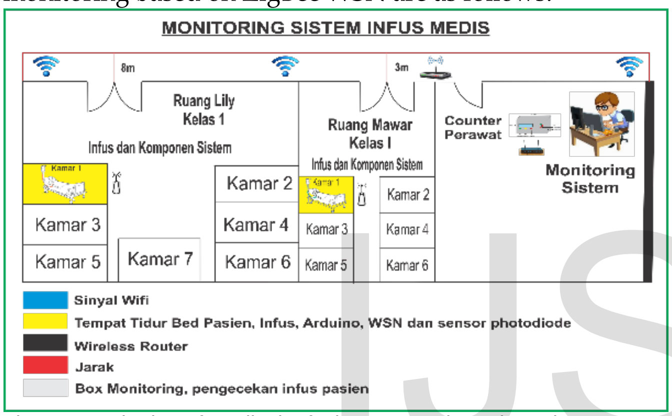

Fig. 12. Monitoring of Medical Infusion System based on ZigBee WSN

While it will output low when the sensor detects the presence of drops of intravenous fluids because infrared light is blocked a split second before being received by photo-diode. Arduino uses the principle of interrupt which means when there is a change from high to low the arduino will assume the sensor is active and output output, when the sensor is active and output output then arduino will start counting drip liquid infusion so that the activity of sensor work better.

The system is turned on by pressing the "on" switch then the 16x2 LCD will display the words "Inflatable Monitoring" as shown in Figure 13.

Fig. 13. LCD Initial Display

When the sensor detects the presence of droplets then the LCD will display the speed of drops / minute and infusion volume. "OK" button to determine the speed value. The display can be seen in Figure 14 and Figure 15.

Fig. 14. Display when There is a Trickle

Fig. 15. LCD Initial Display

The system runs normally when its rated speed is specified and the green LED lights up. Buzzer will sound when the speed drops more slowly four drops/minute or faster four drops/minute from a predetermined speed for example, if the set value speed is 20 drops/minute, then the drip speed is unstable when the value is <16 drops/min or> 24 drops/minute. Display shown on the LCD can be seen in Figure 16 to Figure 17.

Fig. 16. Display System Running Normally

Fig. 17. Display the Infusion Rate Value too Quickly

Fig. 18. Display the Infusion Rate too Slow

The volume view will decrease every drop. If 1cc = 20 drops macro then one drop = 0.05 ml, so each drop will decrease 0.05 ml. The red LED will light up when the fluid volume <20 ml and the LCD will provide the paramedical information to the paramedics to replace the infusion. Display volume <20 ml can be seen in Figure 19.

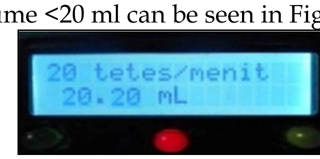

Fig. 19. Liquid Volume Display

3.6. Infusion Testing of Infusion Drops

Testing is done by connecting the infusion drip sensor with the minimum system that has been given ADC reading program by removing ADC data in LCD. In the infusion droplet sensor, testing the optimization of the sensor is to see the change of ADC data. When there are droplets and no droplets on the red LED, green LED, and blue LED, and when closed the casing and without casing. The results of this infusion drip sensor test can be seen in Table 1 through Table 3.

TABLE 1. VALUES OF ADC SENSORS WITHOUT CASING

Infusion Description	Red	Green	Blue
There are drops	+ 573	+ 468	+ 406
There is no droplets	+ 78	+ 56	+ 70

TABLE 2. VALUES OF ADC SENSORS WITH CASING

Infusion Description	Red	Green	Blue
There are drops	+ 732	+ 497	+ 534
There is no droplets	+ 86	+ 52	+ 65

TABLE 3. DIFFERENCE IN VALUE OF ADC SENSOR THERE ARE DROPLETS AND NO DROPLETS

Infusion Description	Red	Green	Blue
Without casing	+ 495	+ 412	+ 336
With casing	+ 646	+ 445	+ 469

From the ADC value difference data obtained, it can be determined the most optimal LED color to droplet changes. The most optimal LED is a red LED, because the red LED has the largest ADC value difference between droplets and no droplets. Difference of ADC value also occurs if sensor closed casing or not. If the sensor is closed casing the difference of ADC value becomes bigger. This is because when the sensor circuit is not closed the casing, the photo-diode receives light from outside, thus reducing the sensitivity of the photo-diode.

3.7. Conversion Test of Drops/Minutes Unit

Testing the conversion of droplets into units of drops/minute is done by:

a. Compare the clock value on Arduino Uno ATmega328P with clock value in real state (real time clock). Xtall used in Arduino Uno ATmega328P is xtall 11.0592 MHz.
b. Instill a unit conversion program of drops/minute on a microcontroller and bring it up on a 2x16 LCD.
c. Test the value of droplet unit/min of microcontroller processing with manual drip/minute counting.

The result of the comparison test of xtall clock value of 11.0592 MHz microcontroller with real state at the same time can be shown in Table 4. From the table above it will get error from microcontroller clock with equation:

$$\text{Eror clock} = \frac{\text{timer-clock arduino}}{\text{clock arduino}} \times 100\%$$

The following table error value Arduino Uno ATmega328P clock test of the comparison of 11.0592 MHz arduino uno ATmega328P clock value with real circumstances at the same time.

TABLE 4. ARDUINO UNO ATMEGA328P AND TIMER CLOCK VALUES

Clock Arduino Uno	Timer
1 seconds	0%
5 seconds	0%
10 seconds	0.1%
20 seconds	0.1%
40 seconds	0.1%

TABLE 5. THE ARDUINO UNO CLOCK ERROR VALUE ATMEGA328P

Clock Arduino Uno	Timer
1 seconds	01.00 seconds
5 seconds	05.00 seconds
10 seconds	10.01 seconds
20 seconds	20.02 seconds
40 seconds	40.04 seconds

Clock Arduino Uno ATmega328P must match the clock in real state. This is because the drip drop speed controller must be able to convert droplets according to units of droplets/min in real circumstances. The probability of occurrence of error value at Arduino Uno ATmega328P clock can occur for several reasons, among others:

a. The compiler program is not good.
b. Inaccurate timer counting.
c. The existence of noise paths that interfere with xtall performance.

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After testing the error value of the arduino uno ATmega328P clock, then the test of drip/minute conversion by arduino uno atmega328P. This test is performed by embedding the drop/minute conversion program and comparing the results with manual counting

Table 8. Overall Testing on Infusion

Data to	Height (cm)	Volume (mL)	LED condition		Buzzer condition	
			Normal	Actual	Normal	Actual
1	10.39	384.74	Green	Green	Off	Off
2	9.98	369.56	Green	Green	Off	Off
3	9.56	354.01	Green	Green	Off	Off
4	9.37	346.97	Green	Green	Off	Off
5	8.83	326.97	Green	Green	Off	Off
6	8.36	309.57	Green	Green	Off	Off
7	8.36	309.57	Green	Green	Off	Off
8	7.13	264.02	Green	Green	Off	Off
9	5.56	205..89	Hijau	Green	Off	Off
10	5.35	198.11	Green	Green	Off	Off
11	4.5	166.64	Green	Green	Off	Off
12	3.79	140.34	Green	Green	Off	Off
13	3.41	126.27	Green	Green	Off	Off
14	2.7	50.98	Red	Red	On	On

Here's the drop/minute conversion,equation

$$\text{speed droplets} = \frac{6}{\text{time lapse drops}} \text{Drops/min} \times 100\%$$

The unit value of drops/minute from arduino processing and manual counting is shown in Table 6.

TABLE 6. DROP RATE VALUES WITH ARDUINO AND MANUAL

Conversion arduino	Time lapse drops	Manual counting
8 drops/minute	7.46 seconds	8.04 drops/minute
14 drops/minute	13.25 seconds	14.11 drops/minute
22 drops/minute	21.69 seconds	22.30 drops/minute
26 drops/minute	25.71 seconds	26.20 drops/minute
35 drops/minute	34.29 seconds	35.08 drops/minute

TABLE 7. DROPLET CONVERSION ERROR VALUES WITH ARDUINO UNO ATMEGA328P

Arduino Uno	Error
8 drops/minute	0.5 %
14 drops/minute	0.78 %
22 drops/minute	1.36 %
26 drops/minute	0.7 %
35 drops/minute	0.2 %

3.8. Overall Testing

System testing process as a whole in control of intravenous fluids can be seen in the scheme Testing. Overall system testing is performed for two infusions (infusions one and two). If the infusion fluid is below 50 mL, then the green led light will be alive, the warning system on the buzzer will be off (not sounding) and the servo motor will not stop the flow of intravenous fluids.

From the whole test on infusion one and infusion two, the result of comparison between normal and actual conditions is the same, the system can work well on the control system of infusion fluids and infusion flow control. Based on the results of system design, system implementation, testing and system analysis, the authors conclude:

a) To design a centralized intravenous infusion monitoring system required several components. The hardware consists arduino uno ATmega328P, LED, LCD, sensor, and Computer connected with wireless sensor network which also functions for data delivery device with client system.

TABLE 9. OVERALL TESTING ON INFUSION II

Data to	Height (cm)	Volume (mL)	LED condition		Buzzer condition	
			Normal	Actual	Normal	Actual
1	8.38	310.31	Green	Green	Off	Off
2	8.01	296.61	Green	Green	Off	Off
3	7.54	279.21	Green	Green	Off	Off
4	7.44	275.50	Green	Green	Off	Off
5	7.39	273.65	Green	Green	Off	Off
6	6.66	246.62	Green	Green	Off	Off
7	5.72	211.81	Green	Green	Off	Off
8	5.7	211.07	Green	Green	Off	Off
9	5.28	195.52	Hijau	Green	Off	Off
10	4.55	168.49	Green	Green	Off	Off
11	4.45	164.78	Green	Green	Off	Off
12	4.29	158.86	Green	Green	Off	Off
13	4.03	149.23	Green	Green	Off	Off
14	1.50	20.20	Red	Red	On	On

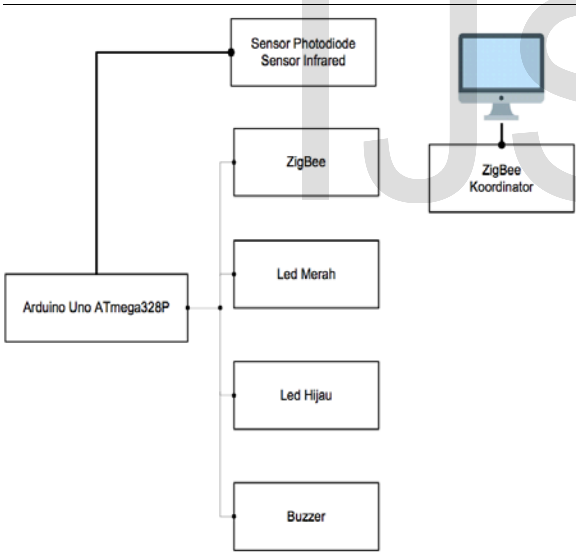

Figure 20. Overall System Testing Scheme

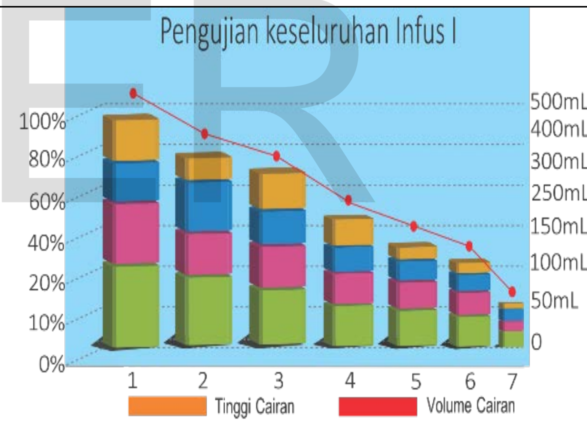

Figure 21. Overall System Testing Graph Infusion I

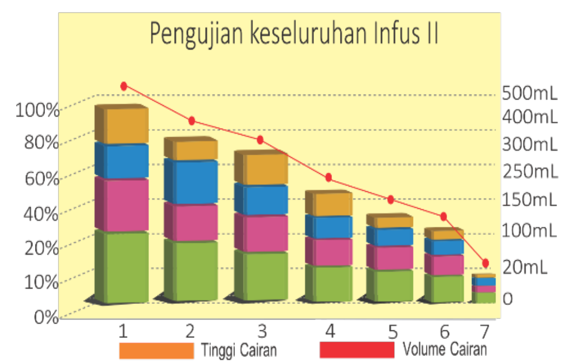

Figure 22. Overall System Testing Graph Infusion II

b) By use arduino ATmega328P, wireless sensor network and pH sensor that has been integrated into an embedded system can automatically analyze the level of intravenous fluid level content and for testing can be done by determining the range of minimum and maximum limits at normal levels.

4. Conclusion

Based on the results of system design, system implementation, testing and system analysis:

a) To design a centralized intravenous infusion monitoring system required several components. The hardware consists arduino uno ATmega328P, LED, LCD, sensor, and Computer connected with wireless sensor network which function also for data delivery device with client system.

b) By use arduino ATmega328P, wireless sensor network and pH sensor that has been integrated into an embedded system can automatically analyze the level of intravenous fluid level content and for testing can be done by determining the minimum and maximum range of limits at normal levels.

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