Prototype of Temperature Monitoring System for BTS Shelter using Android Smartphone

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Abstract. One of the problems with telecommunication devices inside the BTS shelter is the fluctuated heat and voltage, which can cause damage to the device, resulting in disruption of communication between the receiver and the transmitter. This study aimed to design a prototype of temperature monitoring system for BTS shelter using Android smartphone, so that the temperature inside the BTS shelter remains controlled in accordance with the standard temperature. The prototype system uses a chamber with the size of 37.5 cm x 25 cm x 22.5 cm as a simulation of the BTS shelter. The temperature sensor used to detect the temperature inside the chamber is LM35. The cooling system employed in this prototype consists of a mini fan to circulate the cool air generated from ice cubes. The normal temperature of telecommunication device is defined to be in the range of 22ºC to 36ºC. The temperature inside the chamber is displayed in Arduino Bluetooth LM35, which is available on Android smartphones. If the temperature of the chamber exceeds the defined temperature, the cooling system will be active, and when the temperature of the chamber has returned to its normal state, the cooling system will switch off automatically. Based on the results of the temperature detection calibration with Elitech Digital Thermometer, the average %error was 6.9%. This indicates that the design of this prototype should be customized for larger scale.

1. Introduction
The increase use of mobile telecommunication tools results in the development of Base Transceiver Station (BTS), which is a communication device function to receive as well as transfer the radio frequency signal from Mobile Station (MS) to Base Station Control (BSC)[1–3]. The place of BTS is called as BTS shelter that sizes about 3 × 3 meters squared [3]; this shelter is usually located in the remote place, such as mountains, top of hills, etc, so the condition of equipment inside the shelter must be monitored due to the possibility of facing hostile environment, namely rain, fluctuated temperature, etc[4].

One problem related to BTS shelter is the fluctuated temperature inside the shelter; it can be caused by the internal heat generated from the equipment itself as well as the external heat from outdoor temperature and sun radiation. Besides, the size of the shelter contributes to the increase of air temperature inside the shelter. To date, the air conditioner inside the shelter is maintained to be in the range of 25°C-30°C with the highest accepted temperature is 45°C [4]. Therefore, to protect the proper work of BTS inside the shelter, the temperature should be monitored. The usual monitoring procedure is by manually checking the shelter, so it is lack of efficiency.
There are several studies mentioned about monitoring BTS shelter from outside the shelter; Nugroho designed the monitoring system by employing general packet radio service (GPRS) to check the condition of temperature, humidity, voltage and the door of BTS shelter [1]. Anggriawan et al. also constructed the monitoring system using GSM modem to send the SMS to handphone; this equipment used SHT11 as temperature as well as humidity sensor [3]. In addition, Hidayat et al. produce the monitoring device for BTS shelter using DHT11 as a sensor and website to display the temperature [2]. All of the devices mentioned are only for sending the condition of the shelter; still, to fix the condition, the manual procedure should be applied.

Based on the above explanation, this study reported the prototype of temperature monitoring system for BTS shelter using Android smartphone. There is a cooling system in this prototype that is automatically turned on when the temperature inside the shelter is larger than 36ºC and turned off when the temperature decrease to smaller than or equal to 22ºC, so the temperature inside the shelter is maintained. As a simulation of BTS shelter, a chamber with the size of 37.5 cm × 25 cm × 22.5 cm was used, while the cooling system consisted of a mini fan and ice cubes inside a small container. The controller used in the device of the prototype is Arduino Nano since it provides flexible system to work with wireless monitoring [5]. The temperature sensor is LM35; this sensor is widely used to detect the temperature in many room temperature monitoring devices [6–8]. LM35 has low impedance in the output, and the output is also proportionally linear to the temperature (10 mV/ºC), so it can be easily connected to the controller [9]. In order to send the temperature data to the Android smartphone, Bluetooth HC-05 is applied; this component is mostly employed to build wireless communication with operation radio frequency of 2.4 GHz. It is used in this prototype since the power operation is relatively low, namely 1.8V - 3.6V I/O and it can work directly without special driver; the maximum reachable distance is 10 meters[10]. The temperature data is displayed in the LCD outside the chamber as well as on Android smartphone via Arduino Bluetooth LM35 application.

2. Experimental Section

2.1. Design of Hardware
The block diagram of the device in the prototype is depicted in Figure 1; As can be seen, the main components of it are power supply to provide the energy to the entire circuit; LM35 sensor to detect the room temperature, Arduino Nano to control the system; relay to switch on/off the cooling system; mini fan to generate the wind and spread the cool air from the ice cube inside container to the room; Bluetooth HC-05 to transfer the data from Arduino Nano to Android smartphone (Arduino Bluetooth LM35 application), LCD Hitachi – M1632 to display the temperature read by the sensor; and the Android smartphone to display the temperature data from a distant place (up to 10 meters). A box with the size of 37.5 cm × 25 cm × 22.5 cm is utilized as the simulation of the room; a container filled with ice cubes serves as a part of cooling system.

Based on the block diagram, the procedure of how the device works is that when the power supply is connected to the main electrical source, it gives the energy to the circuit, providing energy to the LM35 sensor to detect the temperature inside the chamber. The data read by LM35 is then transferred to Arduino Nano to be processed, if the temperature is still smaller than 36ºC, the signal is sent to the LCD as well as the Bluetooth HC-05, which deliver this signal to the smartphone located far from the chamber. The application used to display the temperature data is Arduino Bluetooth LM35. If the temperature is larger than or equal to 36ºC, the Arduino Nano sends the signal to turn on the relay, activating the mini fan. During this process, the LCD and smartphone keep displaying the data, and when the temperature already drop to smaller or equal to 22ºC, the relay will deactivate the mini fan.
Figure 1. Block diagram of the device

The electrical circuit of the device is given in Figure 2; in this study, the Arduino Nano used is Arduino Nano 3.0 (ATmega328), which has 14 digital I/O pins and 8 analog input pins[11]. As depicted, the power supply of 12 volt is connected to the capacitor of 100 nF as well as regulator IC 7805, so it gives the electrical energy to Arduino Nano. The LM35 sensor is linked to A0 port on Arduino Nano. This prototype applies LCD Hitachi–M1632 with dimension of 16 cm × 2 cm, which is equipped with the driver to covert the ASCII data from the Arduino Nano to the alphabetic character. Here, the use of potentiometer of 5 KΩ to adjust the contrast of the letter appeared on the LCD. The LCD is connected to the ports that have two direction of I/O, and is ADC pins (illustrated in Figure 2). Besides the LCD, this prototype employs the Bluetooth HC-05 connected to the port of TX0 to send the signal to the Android smartphone to display the read data via Arduino Bluetooth LM35 application. The temperature displayed in LCD and Android Smartphone has the same value.

Figure 2. Circuit of the device
2.2. Design of Software
The algorithm of the device is illustrated in Figure 3; the software used to create the program is Arduino AVR, which is a C Cross-Compiler software in which the program is written using C language. The threshold temperature in this device is in the range of 22°C to 36°C. When the device is connected to the power source, the LM35 sensor starts to detect the temperature in the simulation of BTS shelter. If the temperature is larger than or equal to 36°C, the relay will switch on the mini fan of the cooling system to cool down the room, and the LCD as well as the Arduino Bluetooth LM35 application will display the temperature data; otherwise, the relay will not be activated and the device will just present the temperature data on LCD and the application. However, since the range of threshold temperature is 22°C to 36°C, the mini fan will be deactivated if the LM25 reads that the temperature is smaller than or equal to 22°C.

Figure 3. Flowchart of the device
3. Results and Discussion

3.1. Analysis of LM35 Testing

Table 1 provides the data for LM35 testing results; Elitech Digital Thermometer is utilized as a comparison to give the standard data; this device has resolution of 0.1°C and accuracy of 1°C [12]. This measurement is aimed to analyze the % error of the device of the prototype.

| No | Temperature on The Android Smartphone (°C) | Temperature on Elitech Digital Thermometer(°C) | Voltage (V) | Error (%) |
|----|-------------------------------------------|-----------------------------------------------|-------------|-----------|
| 1  | 29.00                                     | 27.10                                         | 4.65        | 7.01      |
| 2  | 27.00                                     | 24.80                                         | 4.68        | 8.87      |
| 3  | 26.00                                     | 24.80                                         | 4.68        | 4.84      |

Average % Error 6.90%

It can be seen that the average %error is 6.9%; this number is relatively high compared to the results found by Elsi, who obtained only 2% of %error [8]. This might occur due to the degradation of LM35 sensor employed in this device, resulting less efficient data. Besides, LM35 has heat generation capability (self-heating), causing errors during the reading process; the temperature of self-heating is around 0.5°C at 25°C [13]. Still, this device can be said to work quite properly since the range of temperature (22°C-33°C) is set under the standard temperature for BTS shelter (25°C-45°C) [4]. However, for the larger scale, the temperature monitoring system for BTS shelter should apply more accurate temperature sensor, such as RTD.

3.2. Analysis of Arduino Bluetooth LM35 Application

In this study, the display of the pressure is presented using Arduino Bluetooth LM35 Application besides using the LCD; this can be seen from Figure 4.

![Figure 4](image)

**Figure 4.** Display of temperature data on Arduino Bluetooth LM35 Application with two different temperatures

Arduino Bluetooth LM35 Application is a special application that is function to display temperature value from LM35 sensor [14-15]. As depicted, the range or temperature that can be monitored by this application is 0°C -100°C; the resolution of the displayed temperature is 0.01°C;
compared to Elitech Digital Thermometer that only has resolution of 0.1ºC. In addition, there is a bar graph under the displayed temperature to show the temperature state. During the testing process, when the application turns on, the temperature will appear directly without delay for the first time; however, when there is a significant temperature change (as given in Figure 4), the appearance of temperature value is delayed for 1 or 2 seconds.

3.3. Analysis of Prototype Testing
To analyse the overall work of the prototype, the test was conducted for six times; there was a waiting time of 10 minutes to obtain different room temperatures. In this study, the testing was conducted in a day from 2:30 PM to 3:30 PM; the time was chosen arbitrary. In order to reach high temperatures (larger than 33ºC), the lighter was turned on inside the chamber carefully. The results are given in Table 2.

| No | Time   | Temperature on Android Smartphone | Mini Fan |
|----|--------|----------------------------------|----------|
| 1  | 2:40 PM| 27.45                            | Off      |
| 2  | 2:50 PM| 27.50                            | Off      |
| 3  | 3:00 PM| 26.50                            | Off      |
| 4  | 3:10 PM| 36.25                            | On       |
| 5  | 3:20 PM| 42.50                            | On       |
| 6  | 3:30 PM| 52.40                            | On       |

Based on Table 2, the device works properly based on the set point given to the controller (temperature range of 22ºC-33ºC). When the temperature was still smaller than 33ºC, the device will deactivate the mini fan otherwise the device will activate the mini fan, cooling down the chamber. Once the chamber already reach 22ºC after cooling down process, the mini fan is turned off automatically. Based on these results, it can be said that this prototype works well to control the cooling system. It can be applied to a real BTS shelter.

4. Conclusion
In summary, the prototype of temperature monitoring system for BTS shelter by using Android smartphone was successfully designed. The device not only monitors the temperature inside the BTS shelter, which is simulated by a chamber, but also controls the cooling system automatically. The Arduino Bluetooth LM35 Application displayed the temperature read by LM35 sensor accurately. Still, this device needs modification on the sensor for the real situation since there is a significant %error in the testing measurement, which happened due to self-heating and degradation of sensor used.

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