Wireless Body-Area Monitoring Network for Outdoor Environment

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Abstract. Energy efficiency is a key issue for outdoor Wireless Body Area Networks (WBANs) that wireless sensor operates near or in human body. WBAN suffered from major problem of energy consumption. As a result, in outdoor simulation based on ZigBee S1 pro type used as transmit and receiver model. The investigation has been carried out based on channel propagation characteristic of what used in simulation based on ZigBee network with multiple sensing nodes, and the design can calculate the channel characteristic such as received power, path loss, path loss free space and path gain. The simulation enables to choose best route to reduce energy consumption depending on the values that have been obtained. Simulation has two routes to using multi point rout to transmit the data from patient nodes to the hospital.

1. Introduction
With the development of Wireless Sensor Network (WSN), the progress in low energy electronics technology lead the WBAN to become a hot spot in recent years. The sensor on surface or transplanted inside the human body can monitor physiological body parameters such as temperature, heart rate, ECG and EMG.

The continued development of wireless technology and inventing of smart wireless devices have opened many aspects for using these technologies on broader horizons [1]. The most interesting usage was for medical issues, where wireless technology used for sending the obtained data from human body to the remote control and then to the hospital for more real-time analysis and diagnostics. In addition, contribute to enhance people life. The limited power batteries were used to supply the necessary power for sensor nodes in WBAN, so reducing energy consumption was an important issue. Although the low energy consumption with development of technology, it should be further reduced to use for long time, it cannot be ignoring that with each increase in distance the energy efficiency becomes less for WBAN.

Many methods have been proposed in recent years to reduce energy consumption, where a variety of energy-saving methods and measures have been proposed and studied. For example, the researchers in [2] proposed an algorithm by increasing duration time in transmission and minimizing transmission energy of a radio link. While, in [3] the researchers proposed a method to create a network to reduce power consumption. In [4] it has been proposed a method to reduce the energy consumption by analyzing and adjusting some parameters for frequency and analog components of the radio. In addition, study the characteristics of sensor network attached to surface of human body when the channel status is good, the power of transport is very high waste energy, also interferes with another sensor body network [5]. Additionally, an algorithm of energy control using model can self-correction...
the Received Signal Strength Indication (RSSI) for ZigBee star network has been presented in [6], where it has been used to reduce the noise of environment to ensure the stability of the transport of the data. In this paper two ways of antenna propagation proposed to create an energy-saving network for sensor that used in outdoor environment organization to extend life of multi-hop sensor. The rest of paper is organized as follows. In section 2 WBAN concepts introduced in details, section 3 presents the performance of method comparing with the practical and ZigBee network model. Finally, section 4 concludes the paper.

2. Wireless Body Sensor Network
At first introduce basics of WBAN, different sensor used in the experiment with ZigBee. By introducing RSSI and transmission power relationships can prove that RSSI value has a linear relationship with distance, but the RSSI value is oversensitive to environmental factors. Therefore, we worked on simulating the outdoor environment based on factors such as distance and received power to find the best connection between the patient and the hospital with lowest usage of power, and the patient has the ability to move from one place to another without any hindrance. Finally, the simulation models for outdoor environment are presented in details.

2.1. WBAN
Which is a wireless sensor network made up of wearable computing devices to monitor the health condition of patients and to enable the doctor to monitor patients’ status remotely without patient review. A typical network of sensor connection can be seen in Figure 1.

![Wireless Body Area Network](image)

Figure 1. Wireless Body Area Network.

2.2. Sensor Network
It has been used three types of sensors in this experiment (ECG, EMG, Blood Pressure) explained briefly, attachment of these sensors to the human body has been clarified in Figure above.

The electrocardiogram (ECG) is a method of collecting electrical signals generated by the heart and works specifically with the electrical activity of the heart [7]. This allows us to understand the level of normal and abnormal heart rate including activation of atria ventricle and recovery wave.

The Electromyography (EMG) is a method used to monitoring the currents produced by the muscles. Muscle effort can be detected by the surface electrodes or within these muscles [8].

The blood pressure sensor measures the human blood pressure. Sensor fit on the finger with small size and it can measure pulse rate, diastolic, systolic and mean arterial pressure [9].
ZigBee are based on IEEE 802.15.4 protocol which has enabled construction of a wireless sensor network and it has been widely used in wireless body area network [10, 11], the ZigBee S1 pro Type are used in this experiment.

3. Simulation and Practical for Outdoor Environment
A system uses wireless technology to monitoring and send physiological data from patient's nodes to hospital in a real time, and has been presented in this work, where patients can wear wireless sensing devices that sense physiological condition and send it to their doctors in real time and used multi hop network to allow the doctors to monitor patients' status remotely. As a result, it has been designed a simulation model for the outdoor environment to simulate and investigate the best method for the process of monitoring the patient. As well as, the case of moving from one place to another and movement of the patient from one place to another which would be manually as shown in Figure 2. This simulation uses a map with three items patient, node and hospital. Ten buttons are located in different places, and two labels that show the position of every item in the map as (x, y) coordinate, which will be explained briefly.

![Simulation Interface and Manual Calculation Window](image)

Figure 2. Simulation Interface and Manual Calculation Window.

3.1. Set Patient / Clear Patient Buttons
Determine the location of the patient on the map and the other button (under it) is to clear patient location and can re-set in any time.

3.2. Set Node / Clear Node Buttons
Determine the location of the node on the map and the other button (under it) is to clear node location, can set about ten nodes and re-set them in any time.

3.3. Set Hospital / Clear Hospital Buttons
Determine the location of the hospital on the map and the other button (under it) is to clear hospital location and can re-set in any time.

3.4. Start Connection Buttons
There are three buttons to start the connection, the first one is related to the first patient and the other two are for patient two and three, but the location of patient, nods and hospital must be set before any connection.

3.5. **Lab Window**

Its work to show the locations of all elements and results of the connections.

3.6. **Calculation Buttons**

This button leads to another window that can calculate the free space path loss, received power, path loss, path gain manually by set the value of transmit power, guard time, green power and distance for the device that will used.

Practically there are a packet sent between the nodes and the controller, Tables 1 explain its content.

| System | Description     | Size  |
|--------|-----------------|-------|
| IDS    | ID Source       | 4-bit |
| IDD    | ID Destination  | 4-bit |
| NH     | Number of Hops  | 4-bit |
| IC     | Information Code| 3-bit |
| P      | Party Check     | 1-bit |
| INF    | Information     | 16-bit|

The graphical user interface that shown in Figure 3 Programmed to obtain the practical result of the system by using the packet information.

![Figure 3. GUI Window.](image)

4. **Results and Discussion**

It has been adopted on equations for (Received Power, Free Space Path Loss, Path Loss and Path Gain) that agreed upon by telecommunications institutions to extract and display values in the lab. Figure 4 shows the instructions that written in C# language to calculate the equations depending on ZigBee parameters.
Function inf(ByVal d As Double)

    Dim lnda As Double = 0.125
    Dim pt, pr, tem, l, lfs, pg As Double
    Dim ptdBm, prdBm, gdBm As Double

    pt = 63 * 0.001
    tem = lnda / (4 * 3.14 * d)
    pr = pt * 1 + 1 + (Math.Pow(tem, 2))
    pr = pr * 1000 ' mW
    lfs = (Math.Pow(tem, 2))
    ptdBm = 10 * (Math.Log10(63))
    prdBm = 10 * (Math.Log10(pr * 1000))
    L = -20 + Math.Log10(tem)
    pg = -1 * L

    lb.Items.Add("Received Power : " & pr)
    lb.Items.Add("Free Space Path Loss : " & L)
    lb.Items.Add("Path Loss : " & L)
    lb.Items.Add("Path Gain : " & pg)

Figure 4. C# code equations for calculating the results.

The flowcharts shown in Figure 5 is representing the process of simulation that proposed respectively. The first route is to detect the nearest node, start connection with it, and do the same pattern with the next node until reach the hospital. This pattern reduces the transmit power unlike the second route that reduces the number of nodes by detecting the longest node in its range and start connection so it reduces the cost of using extra nodes.

![Flowchart](image-url)

Figure 5. flowcharts to connect with nearest and farthest nodes.
For the communication scenarios of Figure 6, calculates the variables of the channels characteristic such as received power, path loss, free space path loss and path gain. The first patient represented by the green color and it used one node with first route for connection between the patient and the hospital, and the blue color belong to the second patient that used two node with second route and the green color is for the third patient that used also two node with second route, for there connection. The channel characteristic results shown in Figure 7.

**Figure 6.** Perform of simulation.

**Figure 7.** Channels Characteristic of Active Node: (A) for Patient 1, (B) for Patient 2, (C) for Patient 3.
The practical measurements are shown as follows, patient was wearing three sensors the first one attached to his right hand to measure the ECG, the second sensor on the left hand to measure the blood pressure, and the third one was connected to his left foot to measure the EMG, and the controller was on his belt to send the data to the next node to the hospital. As shown in Figure 8.

![Figure 8. Practical Wireless Sensor Network.](image)

It can be seen that the improved in power control method saves about 3.1% of total energy at (30 m) of the distance compared to traditional algorithm of power control, to reduce the energy consumed by the transceiver. Figure 9 shows the difference between the practical result and the simulation.

![Figure 9. Relationship between RSSI and Distance.](image)

X-CTU program used to obtain the practical characteristics value of channel, and we have obtained satisfactory results when calculating the channel between the sensors that attached to the human body.
and controller, the best value we got was (-36) dBm, and between the controller and nodes up to the hospital, the best value we obtained was (-72) dBm and the worst value we obtained was (-86) dBm as shown in Figure 10.

![Figure 10](image)

**Figure 10.** RSSI result A: between the sensor and the controller, B and C: between the controller and the nodes to the hospital.

5. Conclusion

This paper explains need of using WBAN, by applying this method to determine the communication between the nodes to control the energy spent in the network due to the changes in dynamic of the human body. The power of the transmitter can be significantly reduced and in an effective manner by using the method proposed, the method can effectively reduce the energy needed for sending the data. System life cycle can be greatly extended using this method. The first route minimizes the energy used for transportation, while increasing the number of nodes to obtain better performance. And the second route reduces number of nodes to achieving the minimum expenses. In the future work, we will improve the simulation by adding the ability of move to the patient's automatically to calculate the characteristics of the channel relative to the moving patient.

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