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Investigation of Signal Strength Level Between Sensor and Sink in Wireless Body Area Network

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***Abstract*—The rapid advances of Information and Communication Technology (ICT) has empowered the development of several application fields. Wireless Body Area Networks (WBAN) is an example of ICT system applications used in medical areas. Combining sensors and wireless communication technology, wireless body area network (WBAN) is one of the most promising fields. One important aspect of wearable health monitoring devices and WBAN is their wireless connectivity. Several technologies can be considered to provide connectivity: Wi-Fi, Bluetooth for local connectivity, cellular interface (2-5G) for mobile access. In this article, we mainly focus on from the website. There are several wireless technologies such as Low power WiFi, Bluetooth, ZigBee and IEEE 802.15.6. In this paper we have analysed experimental evaluation of the signal propagation between sensor and sink according to sensor position on human body and transmission environment using Bluetooth. According to these data was defined the best working performance zones for our WBAN system.**

***Index Terms*— Bluetooth, signal propagation, Wireless Body Area Networks, sensor, Arduino.**

I. Introduction

Advances in Information and Communication Technology (ICT) have brought novel and useful applications to smart healthcare system. The use of wireless technologies and tiny sensors in medicine has a lot of potential to improve healthcare processes that have been studied over the past years. Special wireless devices for health care systems are called Wireless body area networks (WBAN). Wireless Body Area Networks (WBAN) is defined as a kind of ultra-short-range wireless networking technology [1]. Wireless Body Area Networks are a very useful technology which offers a wide range of uses not only to patients but also to the whole society by continuous monitoring. A lot of literature is available related to WBANs. Mostly extensive attempts have been made to advocate solutions for the issues of the WBANs. Before introducing the IEEE 802.15.6 standard, many researchers have been attracted by the concerns of the structure of WBANs and protocols and mechanisms of the physical and MAC sublayer of WBANs.

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WBAN have been studied generally focused on technical issues of WBAN. In scientific and industrial communities, wireless body area networks (WBANs) have been acknowledged as a rising interest by the hopeful prospects across a variety of applications, including remote medical services, sport monitoring, personal entertainments, etc. The WBAN system designs include different frequencies: ISM bands at 400 MHz, 900 MHz, and 2.4 GHz ,ultra-wide band (UWB) [4]. Also, the use of existing short-range communication standards, like Bluetooth and ZigBee/IEEE 802.15.4 at 2.4 GHz, provide a low-cost WBAN solution, has also attracted many studies [2] - [5]. Because the WBAN is the part of wireless sensor networks (WSN) some of the authors analyse information sending and efficient routing [6]-[8].

In this paper we focus on measure Bluetooth signal propagation between sensors and sink according to sensors position on human body and transmission environment.

II. WBAN Network, Applications and Sensors

A. *WBAN network structure*

WBAN systems are based on three layer architecture with the combination of different hardware and software. A WBAN consists of small sensors, which are placed on the body, in the body or close to the surface of the body. These arrangements allow for the continuous monitoring of a patient's condition regardless of the patient's location. These networks consist of several sensors operating on or inside the human body, and transmit collected data to a gateway device that acts as a base station (e.g. smart phone, tablet, PDA, etc.) for real time processing, in order to send medical information and alarms to healthcare providers if an anomaly is detected [9]. Sometimes sensor nodes have actuator to convert an electrical signal into physical signal like motion for pumping. A sensor in WBAN has a primary job to sense any change in physical, chemical or biological entities inside human or around its vicinity. The proposed WBAN network framework is shown in Fig. 1. The proposed architecture of the model is a composite of hardware part and the software part. The receiver that is base station should be able to display the information received from the sensor nodes. Three wireless modules (esp8266, nRF24L01+ and Bluetooth HC-05) nodes were designed and tested to monitor patient's data. An ATmega328 microcontroller is used to design both the sensor nodes and at the base station. These microcontrollers are programmed in C with Arduino platform.

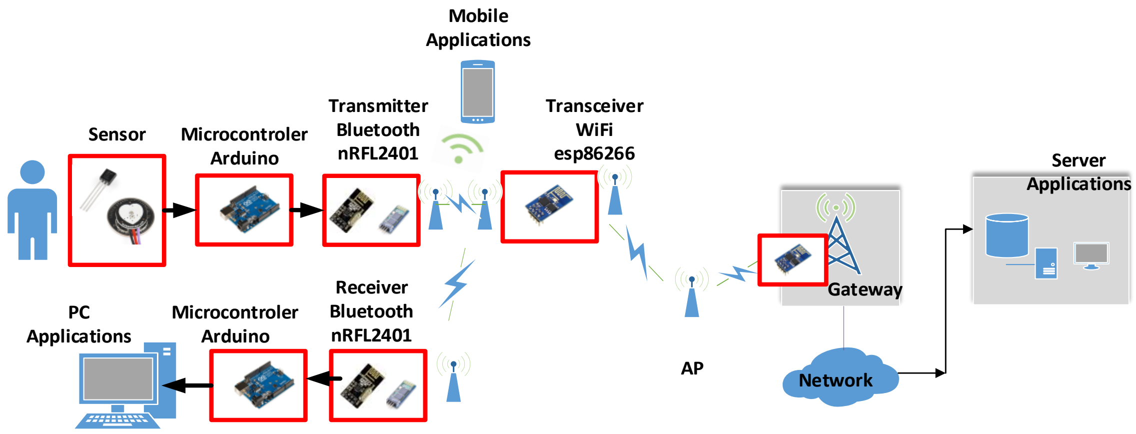


Fig. 1 : Proposed WBAN system

The communication between base station and PC is established by a USB connection or Bluetooth with smartphone. Both devices are used as a display device. Sensors acquire the data and send it to microcontroller. The microcontroller was chosen Arduino Uno. The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button [10]. Sensors (temperature and pulse rate sensor) send the analogy data to micro-controller. To make the data understandable to microcontroller it needs to be converted into digital form. It is done with the help of an ADC convertor which is integrated in the microcontroller. A microcontroller is used to interface sensors and wireless transceiver. PC is used as a display device for visualization data. The work flow chart of the proposed system is presented in Fig.2

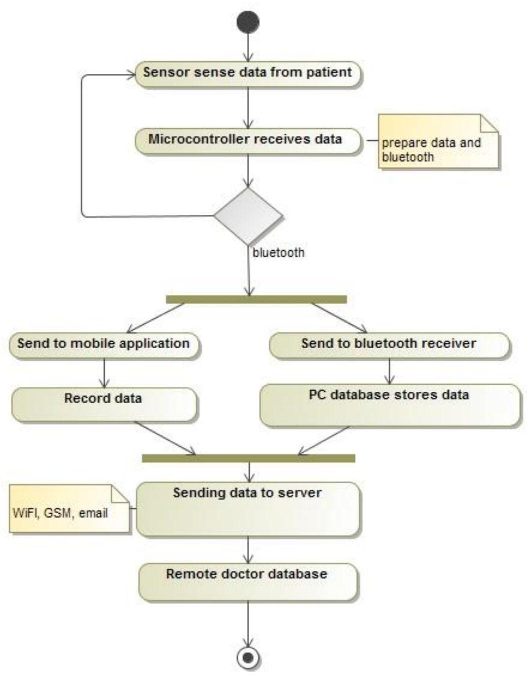


Fig. 2: Work flow chart of the proposed system

When the patient takes a sensor result, then he will transfer this result to the smart phone using Bluetooth technology. The user, using mobile application on cell phone will store this result into the internal database and if he wants to send to the web service or send txt file to email or SMS. The patient's doctor will get a notification to look at the test result and give the feedback to the patient.

WBAN may involve different technologies at different levels. ZigBee communication is specially built for control and sensor networks on IEEE 802.15.4 standard for wireless personal area networks (WPANs), and it is the product from ZigBee alliance. This communication standard defines physical and Media Access Control (MAC) layers to handle many devices at low-data rates. These ZigBee's WPANs operates at 2.4 GHz, 950 MHz, 915 MHz, 868 MHz, 780 MHz, 500 MHz, and 3.1–10.6 GHz frequency bands. The capacity is 250 Kbps at 2.4 GHz, 40 Kbps at 915 MHz, and 20 Kbps at 868 MHz Some devices have an indoor communication range of 50 m, outdoor range of more than 500 m. Bluetooth is a wireless technology used to transfer data between different electronic devices. Bluetooth devices operate in the 2.4 GHz ISM band (Industrial, Scientific and Medical band), utilizing frequency hopping among 79 1 MHz channels at a nominal rate of 1600 hops/sec to reduce interference. The standard specifies three classes of devices with different transmission powers and corresponding coverages ranging from 1 to100 m. The maximum data rate is 3 Mbps. WiFi is an IEEE 802.11 standard for wireless local area network (WLAN). Nowadays WiFi technology popular standards are 802.11 g/n and 802.11 ac, that runs in ISM band 2.4 and 5 GHz with a modest coverage of 200 meter.

B. WBAN network applications and sensors

WBANs have great potential for several applications including remote medical diagnosis, interactive gaming, and military applications [11]. In-body applications include, monitoring and program changes for pacemakers and implantable cardiac defibrillators, control of bladder function, and restoration of limb movement. On-body medical applications include monitoring ECG, blood pressure, temperature, and respiration. Furthermore, on-body non-medical applications include monitoring forgotten things, establishing a social network, and assessing soldier fatigue and battle readiness.

WBANs sensors have various functions and are responsible for monitoring different physiological information. Each sensor node can sense, sample, and process one or more physiological signals. A sensor node performs three mains tasks: signal detection, signal digitization/coding/controlling for communication that involves multiple accesses and finally transmitting the data through a transceiver wirelessly. The signals that are received from human body are not strong and are accompanied by noise. An electrocardiogram sensor (ECG) can be used for monitoring heart activity, an electromyogram sensor (EMG) for monitoring muscle activity, an electroencephalogram sensor (EEG) for monitoring brain electrical activity, a blood pressure sensor for monitoring blood pressure. Monitoring blood pressure at home is important for many people, especially if you have high blood pressure.

III. The Experiment Setup of Bluetooth Signal Strength Level Measurement

A. The specifications of experimental setup

The aim of these experiments is to measure sensor Bluetooth signal strength in the sink using different cases, because it influences of wireless sensor battery lifetime, which is the one of the main parameters of good WBAN performance. The experimental scheme for received signal level measure is presented in Fig. 3

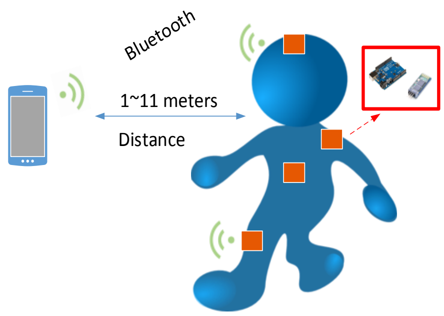
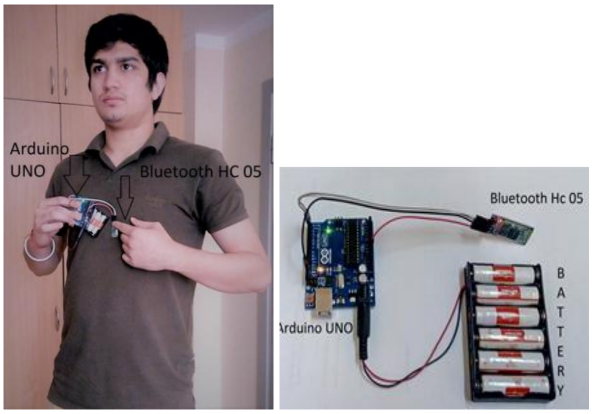


Fig. 3: Proposed WBAN system

The initial main parameters are tabulated in Table 1. In our measurement setup equipment was used: Bluetooth (HC 05), Arduino UNO, Battery, Android mobile. Fig.4 (a) and (b) show the measurement setup for the experiment sensor on body and basic experimental material setup. Connect Bluetooth (HC 05) with Arduino UNO and battery is connected to the Arduino UNO. This Bluetooth setup is placed on the patient and then I pair Bluetooth device with android mobile by entering default password 0000. Then download the application from the android mobile to analyses the Bluetooth signal level of the patient.

Table 1. Experimental setup for measuring signal level

Parameter	Value
Sensor positions	Head, shoulder, Chest, knees,back
Distance	From 1 to 11 meters
Human rotation	180 and 0
Wall	Air, glass,wood,wall
Technology	Bluetooth
Measure	10 measures in all events positions
Measure parameter	Received signal level



(a) (b)

Fig. 4 : Sensor on body (a), basic experimental material (b)

Application name is Bluetooth signal and I measure the signal level in different environment like Air medium, Glass medium, wood door medium and wall medium. There are many locations on your body where you could wear sensor node. The different position of the patient like Head, Shoulder, Chest, Knee and Back was analysed. Continuously increase the distance of the Bluetooth which is place on the patient and take the reading 10 times at different Distances. Distance range is varying from 1 meter to 11 meters. We take average of 10 values at all distance ranges. Bluetooth signal application is good application for measuring the signal level of Bluetooth and for more accuracy. For each of these cases, measured the RSS emitted by ASUS mobile phone application. The abbreviations and symbols which are using in the graph are in Table 2.

Table 2. The abbreviations and symbols

A – Air medium	G–Glass medium	D–Door medium
W–Wall medium	H – Head	S – Shoulder
C – Chest	K – Knee	B – Back

B. Results of experimental measure

The comparative analysis of different measurement case are presented in fig. 4-7. Becouse we had many rezults, only few of them presenting in this article. According our results with polynomial regression we can fit models of order n > 1 to the data and try to model nonlinear relationships.

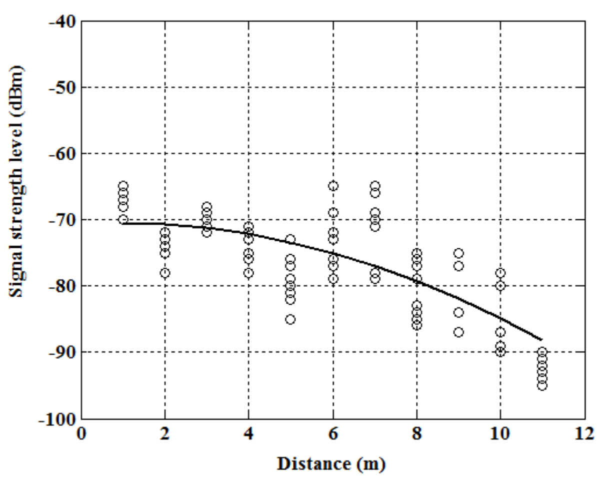


Fig. 4: Signal strength level versus distance on back sensor positions on human body and environment-air

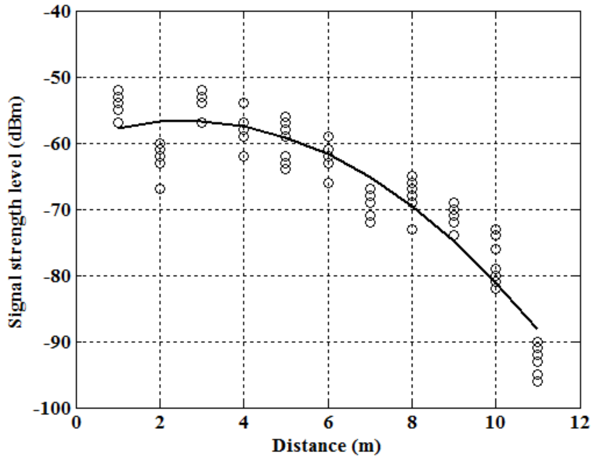


Fig. 5: Signal strength level versus distance on knee sensor positions on human body and environment- door

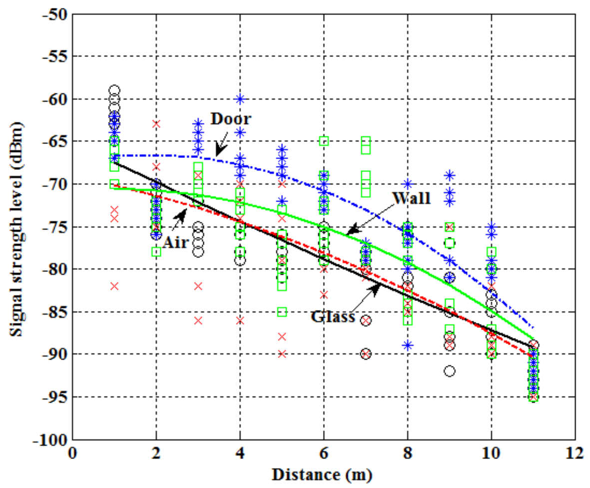


Fig. 6: Signal strength level versus distance on back sensor positions on human body on different environment

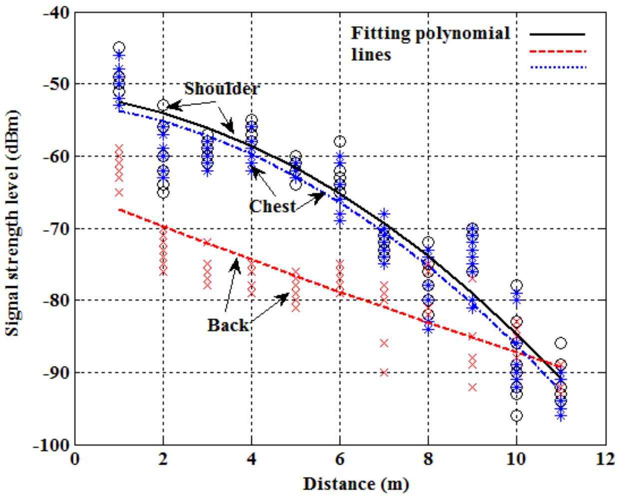


Fig. 7: Signal strength level versus distance on different sensor positions on human body and environment- air

Analysing the results we can see when sensor on head the maximum value of signal level is -48dBm and minimum value of signal level is -90dBm. In all cases, the signal level is decrease as increase the distance but at 4 meters distance the signal level is little bit increase because of reflection of the signal from the wall of the room. The graph of the shoulder, chest and knee is almost same but the graph of the back is very different from all position. The maximum value of signal level at back is -62dBm and minimum value of signal level at back is -92dBm. And the behaviour of the graph is almost linear. All graphs are decrease with distance in the shape of curve except Air medium on back.

The fitting polynomial model's coefficients of experimental results are given in Table.2

Table 2 Fitting polynomial model's coefficients

Mathematical Model $S = ad^2 + bd + c$	**a**	**b**	**c**
Air(A)			
Head (H)	-0.2333	- 0.8873	- 51.0430
Shoulder(S)	-0.2512	- 0.8178	-51.1485
Chest(S)	-0.2576	- 0.7291	- 51.5679
Knee(K)	-0.2664	- 0.6810	- 52.8036
Back(B)	-0.0200	- 2.4133	- 65.0606
Glass(G)			
Head (H)	-0.3503	+ 1.5351	- 56.8764
Shoulder(S)	-0.3519	+ 1.6487	-57.4794
Chest(S)	-0.3818	+ 1.9582	- 57.8491
Knee(K)	-0.3415	+ 1.4597	- 56.7588
Back(B)	-0.0854	- 0.9866	- 69.0958
Door(D)			
Head (H)	-0.4256	+ 2.1077	- 59.6939
Shoulder(S)	-0.4520	+ 2.5220	- 60.5770
Chest(S)	-0.4516	+ 2.3859	- 59.7679
Knee(K)	-0.4382	+ 2.1733	- 58.7448
Back(B)	-0.2421	+ 0.8822	- 67.3667
Wall(W)			
Head (H)	-0.2400	- 0.5194	- 57.4085
Shoulder(S)	-0.3228	+ 0.3541	- 58.0012
Chest(S)	-0.3217	+ 0.4129	-58.0982
Knee(K)	-0.3235	+ 0.4425	- 57.6994
Back(B)	-0.1738	+ 0.3135	- 70.6418

C. The comparison of results

Air

Good signal strength on Head, Chest, Shoulder and knee but on back there is the resistance of the signal because of human body. And minimum signal level is also high as compare to other medium. Best position area is shoulder. I get good signal strength on 4 meters because of reflection of the signal.

Glass

Because of glass medium the range of signal level is almost same and reduction of signal is less as compare to other medium. The distribution of signal level is constant in room. Good zone for back is less than 1 meter. Maximum signal level is -53dBm. Head is good position area for Bluetooth. Bad signal strength for back. The range of signal strength due to reflection is more as compare to other medium (Range: 6 to 9 meter).

Door

In this medium signal strength is not good as compare to air and glass medium. Signal level is decrease at 2 meters. Good position area is chest. Minimum signal level is -92dBm. Accepted zone for all position is more than 10 meters. In this medium Good Zone at (head, shoulder, chest and knee) is 1 meter and 3 meters to 5 meters only.

Wall

In this case wall has good resistance for signal strength so in this medium Good Zone at (head, shoulder, chest and knee) is at 1 meter and 3 meters. Accepted zone is till 7 meters. Knee is the best position area and bad position area is back because of human body resistant. Maximum signal level is -55dBm which is less as compare to other zones.

D. Creating working performance zones

Combining all measure results we plot the graph of relationship between signal level and distance. Figure 8 illustrate the distribution signal strength of all measures. Using approximation and software Matlab was created Bluetooth WBAN working zones.

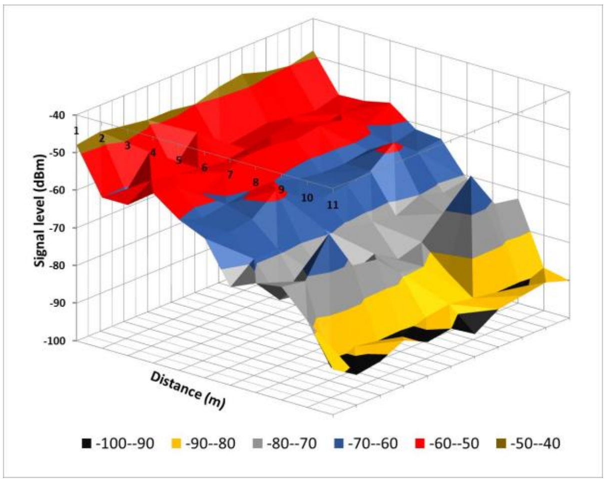


Fig.8 Signal strength level versus distance

As showing fig. 8, we have 6 ranges of signal strength like: -100dBm to -90dBm, -90dBm to -80dBm, -80dBm to -70dBm, -70dBm to -60dBm, -60dBm to -50dBm and -50dBm to -40dBm. Fig.8 represents these ranges in different colour and we can see the range of Bluetooth signal strength.

As increase the distance of the Bluetooth device the strength of the device become low. It was observed that had been see 3 zones, where minimum dispersal of signal. Therefore, using mathematical interpolation analysing fitting polynomic models together with experimental results we defined 3 working zones for Bluetooth technology: good, accepted and bad. After that we define 3 zones, which are presented in fig.9.

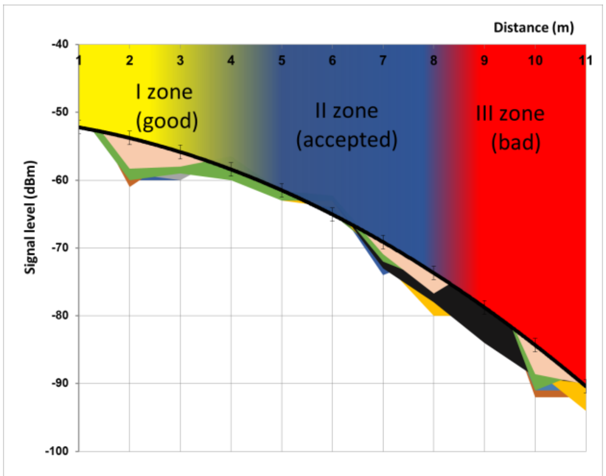


Fig.8 Working zones for Bluetooth technology according to signal strength level and distance

We can see that there are three zones present in this graph. 1 good zone, 2 accepted zones and 3 bad zones. We divide the signal level strength in three zones good zone is good for communication and there will be no problem when transfer the data. Accepted zone is also good for communication but in bad zone communication will be not good and minimum signal strength in this zone.

IV. Conclusion

1. In Bluetooth signal strength level experiment, there are three zones, Good zone- until 4 meters, accepted zone- until 8 meters and bad zone- more than 8 meters and Signal strength level increases suddenly because of reflection of the signal from the wall of the hospital as we go far from the Bluetooth device.
2. In Bluetooth signal strength level experiment, the Maximum signal level and minimum signal level of Bluetooth in air, glass door, wood door and wall medium are -48dBm to -94dBm, - 53dBm to -91dBm, -54dBm to -92dBm and -55dBm to -93dBm respectively.
3. In Bluetooth Experiment, Bad position area is back in every medium and good position area in air, glass door, wood door and wall medium are shoulder, head, chest and knee respectively. Also analyze mathematical model for each case.

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