The Performance Analysis of Different Propagation Medias in Medical Body Area Network

P.M. Sruthi and T.K. Parani

Abstract--- Wireless Body Area Network (WBAN) is wearable computing network. WBAN is one of the promising technologies in Wireless Sensor Network (WSN). WBAN is one of the upcoming techniques in medical field. The depth understanding of the propagation media is essential for the design of efficient wireless communication protocols for the medical BAN. This article aims at analyzing three different propagation Medias like Radio Frequency (RF), Optical Wireless Communication (OWC) and Ultrasonic Navigation. The comparative study of various parameters like end to end delay, throughput and data transmission speed of propagation medias are performed. The simulated results showed that ultrasonic navigation propagate with maximum speed, throughput and minimum delay**.**

Index Terms--- Medical Body Area Network, RF Technology, Optical Wireless Communication Technique and Ultrasonic Navigation Technique.

I. INTRODUCTION

In recent world the network technologies are facing major challenge in efficient data transmission. To obtain best transmission result the data should transmit with minimum delay and maximum throughput. This problem highlights in Wireless Body Area Network while it applies in medical applications. In Bio BAN [10] applications the physical condition of the patient should reach the physician in maximum speed with minimum packet loss. Here it shows the importance of the propagation media that used. The technology developers invented different wireless propagation media according to the need and importance of data transmission. Radio Frequency channel, Optical Wireless Communication and Ultrasonic Navigation are the propagation medias that used in recent world. Each propagation medias contain unique properties. In Radio Frequency propagation media the data propagates in the form of electromagnetic waves. Radio[14] waves are effected by diffraction, reflection, polarization, refraction, absorption and scattering. RF propagates through the upper atmosphere (ionosphere). RF is [6] affected by the changes of water vapour in the atmosphere and ionization in the upper atmosphere due to the sun. 70 percentage of human body is composed of water, a medium that absorbs the electromagnetic waves significantly. Optical Wireless Communication use [4] unguided visible ultraviolet light to carry signal. OWC commonly referred as Visible Light Communication (VLC). VLC takes advantage of LED (Light Emitting Diode) which can propagate at high speed without noticeable effect on lighting output and human eye. In Ultrasonic Navigation signal propagates [15] as sound waves with the frequencies higher than the upper audible limit of human hearing. In its physical properties ultrasound have no difference from normal audible sound, except in this human cannot hear it. In this paper, all these three propagation medias are analyzed by taking application on Medical Body Area Network.

P.M. Sruthi, II ME(Applied Electronics), Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamilnadu. E-mail: sruthiimohanan@gmail.com

T.K. Parani, Assistant professor, Department of ECE, Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamilnadu. E-mail: parani30@gmail.com

Wireless Sensor Networks consist of several specialized transducers that connected in network infrastructure for monitoring and recording the condition of a location. The monitored parameters are temperature, pressure, humidity, wind direction, vibration intensity, and etc. The network consists of the following detection stations called sensor nodes. The sensor nodes are provided with microcomputer, power source, and transceiver. Based on the sensed physical effects the transducer will generate the electrical signal. The microcomputer function is to store the sensor output. The central computer sends command to the transceiver and transceiver transmits the data to the computer according to the command. The power for each sensor is driven from the battery.

Wireless Body Area network (WBAN) or Bio Sensor Network is the combination of micro and advanced Nano technology. BAN devices considerably suitable in any scenario like health monitoring, sport and military applications due to its considerable light weight, low power, and sensing capability.

BANs [5] are primarily designed to monitor the health status. BAN used in hospitals as interface of diagnostics process. The benefit of this technology is that can monitor patients with chronic disease like asthma and diabetics more closely. Therefore doctor can update the patient's record quickly and efficiently. By taking the importance of BAN in medical applications, it is essential to transmit the data efficiently. It can achieve by choosing the best propagation media.

A feasibility study on [16] Wireless Body Area Network for Health care gave the knowledge about the system that used for BAN and about the challenges that faced by the WBAN in On body and In body sensor network. The sensors are one of the important factors in BAN, it collect data's from the body. In body sensor network, the sensors are embedded inside the body, so frequent replacements of the sensors are quite difficult. For achieving better performance in sensors the batteries of implants should perform efficiently. The propagation media is also having a major function in battery life. The sensor should radiate the signal in low power. RF waves need to transmit at high power because absorption of electromagnetic waves that occur inside side the body. And the implantation of Visible Light System (VLS) inside the human body will harm human tissues. But ultrasonic sound waves have significantly lower absorption in human tissues and harmless. Ultrasonic navigation obtained better results in this comparative study of different propagation media.

The paper is organized as follows. Section II studied about the analysis system that used and about the propagation medias. The output analysis and its comparisons are described in section III. Finally conclusion is described in section IV.

II. EXPERIMENTAL METHODS

A. Analysis System

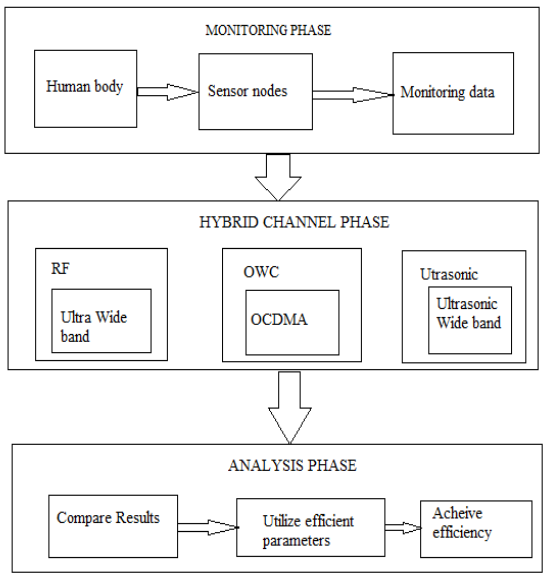

Fig. 1: Block Diagram for Analysis System

Figure 1 shows the block representation for the propagation analysis system. From human body sensor nodes collected the data and it stores in a system for monitoring. Data's are transmitted to the destination point through the desired propagation path and in the analysis phase the performance of the propagation path is compared.

i. Sensor

Sensors are type of transducers that collect the data from body and covert that to corresponding form of output (Electrical, Optical or Ultrasonic waves). The progress in technology allows more sensors that to be manufactured on a microscopic scale as Micro Electro Mechanical System (MEMS). MEMS are made up of component between 0.001 and 0.1 micrometers in size. It consists of central unit that process the data and the component interact with the surrounding. In bio medicine the sensors will detect the biological component, such as cells, nuclei etc. The encapsulation of biological data in biosensors is different from the ordinary sensors because to sense the biological value, the sensor should act as more sensitive it should sense and collect the data even if any small changes in the human body.

The two types[17] of biosensor network are on body sensor network and in body sensor network. On body sensor network is that the sensor will be placed on the skin surface. The micro as well as the Nano size of the sensor won't feel any disturbance to the patient. The sensor is differentiated according to the function that performs; there is temperature sensor, ECG (Electro Cardiogram) sensors, EEG (Electro Encephalography) sensors, EMG (Electro Mammography) sensors etc. The temperature sensors used to sense the temperature. ECG sensors for monitoring heart functions, EEG sensors oversee the function of brain and EMG sensors to recognize the changes in muscles.

In body sensors are embedded inside the body that can monitor the nerves functionalities. The sensors that having size as dust particle that can monitor the brain nerves are the recent research that going on.

ii. Ultra Wide Band Technology

In Radio frequency propagation the Ultra Wide Band (UWB) technology is used [12,13]. It is the technique that used for transmitting information spread over a large bandwidth (>500 MHz). The Federal Commission of Communication allocates the bandwidth from 3.1GHz to 10.6 GHz for unlicensed radio applications. The channel capacity of a properly encoded signal is proportional to the bandwidth of the channel, thus the capacity of the channel increases linearly by increasing by increasing the channel's bandwidth to the maximum value available. Without invoking higher order modulations by virtue of the large bandwidths inherent in UWB systems, large channel capacities can achieve with requiring a very high SNR. It will increase the efficiency of the system.

iii. Optical Code Division Multiple Access

Optical Wireless Communication uses Optical Code Division Multiple Access (OCDMA) technique. The advantage of using this technique is, network granularity and the flexibility in the management of the system resources, has the potential of supporting burst IP traffic and multi-protocol based network and it applicable where security in transmission is important. OCDMA allocates each user of the network with a particular code, before transmitting the codes are assigned to the data pulses. In order to establish communication at the receiver the users rely on correctly decoding the signal intended for them.

iv. Ultrasonic Wideband Technique

Ultrasonic Wideband is a multiple access technique that Transmit short information-bearing carrier less

ultrasonic pulses, which follows a pseudo-random adaptive time-hopping pattern that contain a super imposed spreading code for adaptive length. Impulsive transmission will generate Intersymbol Interferences (ISI). When the redundant pulses reflected are received with a differential delay that equal to the pulse width, they do not overlap with the original pulses. Therefore, the Intersymbol Interferences are reduced and multiple propagation paths can be efficiently resolved. It can combine at the receiver to reduce the bit error rate. Therefore, the efficient transmission of data in ultrasonic navigation can achieve. It is the latest research that performing in the Wireless Body Area Network (WBAN)

B. Radio Frequency(RF)

RF propagation is[1] the behavior of electromagnetic waves or radio waves that propagated from source to destination.

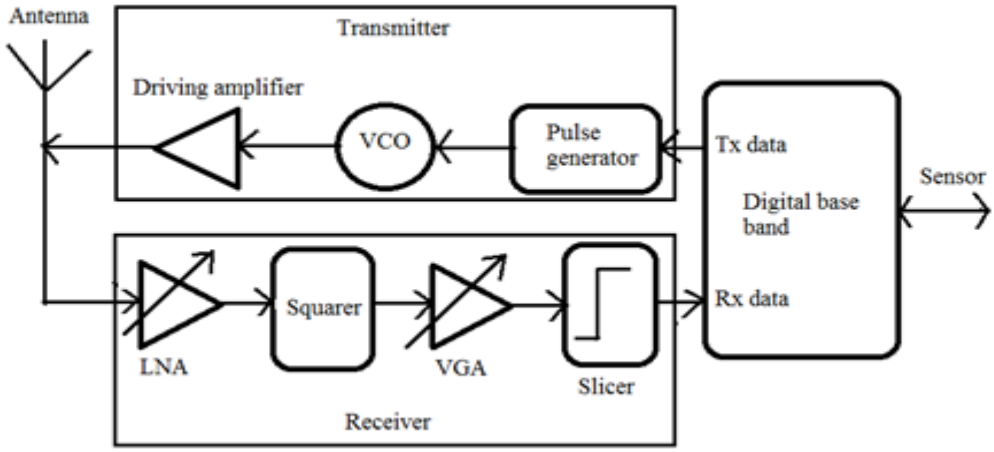

Fig. 2: Block Diagram of RF Propagation

In figure 2, in transmitter section the sensors act as the transducers and get data from the body and coverts that in to the electrical signal. The pulse generator is electronic equipment that used to generate the rectangular signals, here the signals that received from sensors are converted in to pulse signal. Voltage Control Oscillator (VCO) is electronic equipment that controls the frequency by an input voltage. Linear VCO is used in this system that generates the sinusoidal output, to prevent the amplitude from decaying the VCO consist of resonators with amplifier and isolates the resonators from output so the load does not affect the resonator. The harmonic oscillators are crystal oscillators and LC tank oscillators. Here it uses crystal oscillator for better performance. The driver circuit is electronic devices that used to control other equipment's that connected to the system and used to regulate the current flowing through the system and the amplifier in the circuit that amplifies the signal and drives to antenna.

In receiver section the Low Noise Amplifiers (LNA) are designed to minimize additional noise, the circuit that used to amplifies very low power signals without any degradation in SNR (Signal to Noise Ratio). LNA will increases the power of both signal and noise that present in the input but it will minimize the additional noise by considering trade off and impedance matching. LNA will supply the power gain of 20 decibels and it will decrease the noise ratio in the system. Squarer circuit will doubles the frequency and increase the

strength of the input signals and give out the output. Then the voltage gain amplifier varies the gain according to controlled voltage and the slicer will select the desire signal in the receiver section.

RF propagation is effected by electromagnetic interference and while considering intra body sensor network, 70% of the body is filled with water so body will absorb electromagnetic radiation there for the sensor need to consume more power to radiate the output so the battery won't last for long.

C. Optical Wireless Communication (OWC)

In OWC [2] unguided visible infrared (IR) or ultraviolet (UV) is used to carry signals. It will propagate faster than RF. It attains Qos because the light ways can't penetrate through the wall and it is free from electromagnetic interference [8]. It performs better than RF. But it gives better performance only in a closed surface [11].

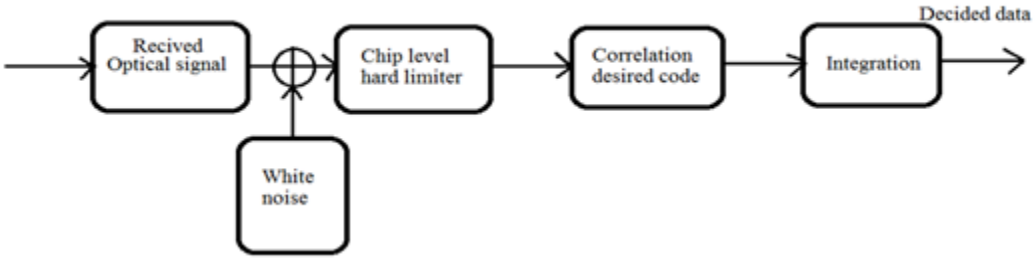

Fig. 3: Block Diagram of OWC Propagation

$$(t) = \mathrm{x}(t) \otimes h(t) + n(t) \qquad (1)$$

Where,

y(t)= output

x(t)= input signal

h(t)= impulse response of the optical channel

n(t)= white Gaussian noise

In equation (1) the output performance of the OWC system is calculated. In figure 3, Optical signal is added with white noise. White noise are random signals that having same intensity throughout different frequencies and gives constant power spectral density. White noise is referred as the statistical model for signal resources and signals. By using Chip level hard limiter circuit, multi user interference can reduce and can reduce the sensitivity of system. Correlation desired code will check how much they received signal matches the desired code and the integration block will integrate the signal and gives out the output.

D. Ultrasonic Navigation

It is ultrasonic sound waves [3] having the frequencies higher than the upper audible limit of human hearing it ranges from 20 KHz to 200 MHz

Ultrasonic sound easily [18] penetrates through the water molecule so in intra body sensor network the ultrasonic navigation will perform better than other propagation media. The propagation speed of the sound wave is higher than other RF and OWC. Attenuation refers to reduction in signal strength, it is also known as loss in signals. Absorption and scattering are two mechanism's that contribute the ultrasonic attenuation. The absorption is less while characterizing the human tissue. Ultrasonic waves operates in higher frequencies, therefore it will help to keep the transducer size small

because the operating frequency of ultrasonic waves depends on the beam spread of ultrasonic transducer, which is inversely proportional to the ratio of the diameter of the radiating surface and the wavelength. By using ultrasonic navigation the video monitoring for implantable devices also can perform effectively. Analysis of streaming video performance shows, the Peak signal-to-noise ratio (PSNR) [7, 9] compares the maximum possible image energy to the noise energy, which have higher correlation with the subjective image quality perception.

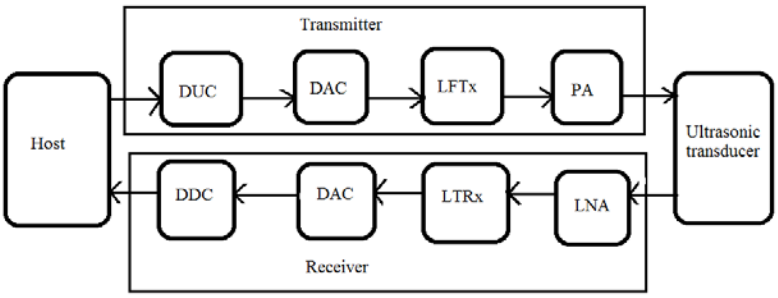

Fig. 4: Block Diagram for Ultrasonic Navigation

In figure 4, Host act as the desk top or computer on module, the host machine runs all the software-defined signal processing. The signal passed through the Digital Up Conversion (DUC) then that signal will covert to analog signal by passing through Digital to Analog Converter (DAC) and low frequency signal is generated and passed through the Power Amplifier (PA) that amplifies the power of the signal and make the signal strong. Then the transducer will give out the ultrasonic waves with respect to the input. In receiver section the sound waves are passed through the Low Noise Amplifier (LNA) that reduces the noise effect and interference in the signal then the low frequency signal is produced and that signal converted in to the analog signal by passing through DAC then Digital down Conversion (DDC) transmitted the signal to the host.

E. Formulas Used for Calculating Data Rate

a. Delay time = End time – Start time

b. Delivery Ratio = (Received data/ Generated data +1)*100

c. Throughput = (End time – Start time)* 100

Using these formulas the delay time, delivery ratio and throughput of the propagation medias are calculated. The comparison of data rate obtained by propagation medias are explained in section III

III. RESULTS

Throughput, delay and transmission speed of the propagation Medias are compared. And the data rate analysis is performed for each propagation media. Transmitted data, received ratio, delay time, throughput are calculated by mathematical formulas.

A. End to End Delay

End-to-End delay is the time taken for a packet to transmit across the network from source to destination. It depends on the following parameters:

- Nodal processing-Effect is occurring by check bit errors.
- Queuing-Depends on congestion level on router and time waiting at output link for transmitting.

- Transmission delay-Affected by link bandwidth, packet length.
- Propagation delay-Occurred by length of physical link and propagation speed in the medium.

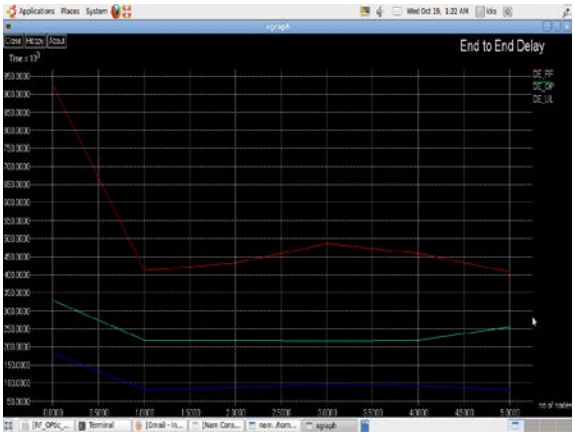

Fig. 5: Graph Obtained for End to End Delay Analysis of RF, OWC and Ultrasonic Navigation

In figure 5 it shows that, the delay is less in ultrasonic propagation while comparing to RF and Optical.

B. Data Transmission Speed

Data transmission speed is the rate at which the data are moved across the communication channel. It is effected by the nature of the propagation media.

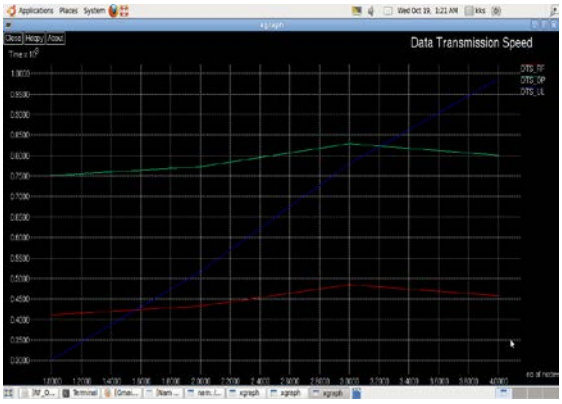

Fig. 6: Graphical Output Generated for Data Transmission Analysis of RF, OWC and Ultrasonic Navigation

In figure 6, Data transmission speed is high in Ultrasonic Navigation than RF and Optical wireless communication.

C. Throughput

Throughput is a measure of how many unit of information a system can process in a given interval of time. While defining in data transmission, the throughput of a network is the amount of data moved successfully from one place to another in a given period of time and it is measured in bits per second. The throughput of the communication system affected by various factor,

a. The limitations of underlying analog physical medium.
b. Processing power of the system component.
c. End user behavior.

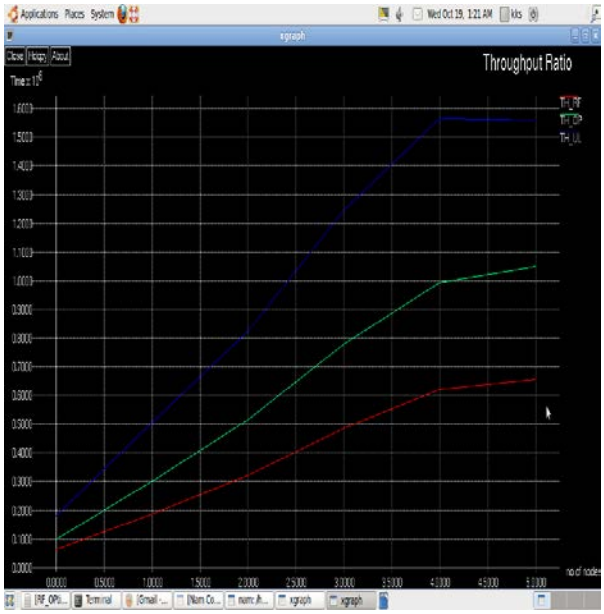

Fig. 7: Graph Obtained for Throughput Analysis of RF, OWC, and Ultrasonic Navigation

From figure 7, it is concluded that, data received through ultrasonic propagation media is high while comparing RF and Optical.

D. Data Rates

The data rates that obtained for propagation Medias are explained.

Radio Frequency

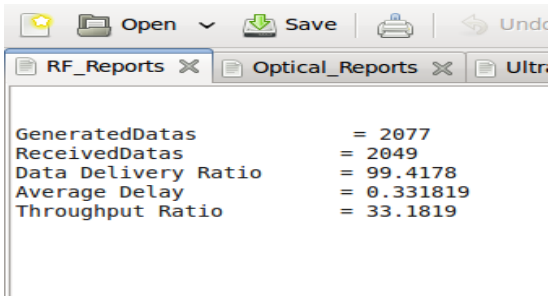

Fig. 8: Data Rates Generated by RF

Optical Wireless Communication

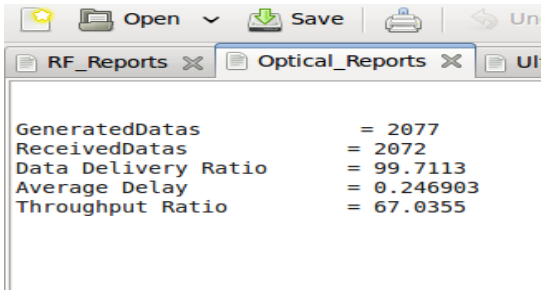

Fig. 9: Data Rates Generated by OWC

Ultrasonic Navigation

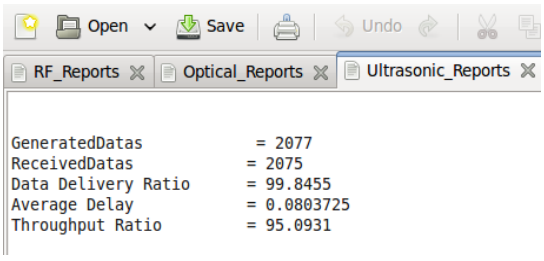

Fig. 10: Data Rate Generated by Ultrasonic Navigation

Figure 8, 9 and 10 showed the data rates that obtained by Radio Frequency propagation, Optical Wireless Communication and Ultrasonic Navigation. By analyzing these three data rates it is proved that Ultrasonic Navigation transmit the data with least average delay 0.080μs and highest throughput 95.09%, therefore the ultrasonic performs better than RF and Optical with high throughput, more speed and minimum delay.

IV. CONCLUSION

From this analysis it is concluded that ultrasonic navigation show's better performance than the RF and Optical Wireless Communication.

Table 1: Comparison Table of Different Propagation Medias

PARAMETERS	*RF*	*OWC*	*ULTRASONIC*
Generated data	2077	2077	2077
Received data	2049	2072	2075
Data delivery ratio	99.41	99.71	99.84
Average delay (μs)	0.33	0.24	0.08
Throughput (%)	33.18	67.03	95.09

From Table 1, the data rate obtained by each propagation medias are compared. Radio Frequency obtained packet loss in higher level and Ultrasonic shows less loss. While comparing the delay of the system, ultrasonic shows better performance with minimum time delay. Then the throughput is maximum in ultrasonic and minimum in RF. It is concluded that ultrasonic propagation media is better than OWC and RF.

In future the work can be extended by improving the performance of the Ultrasonic propagation media by increasing the efficiency of the system.

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