

## Energy Efficient Adaptive Routing Protocol For Wireless Body Area Networks (WBAN)

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**Abstract:** A Wireless Body Area Network (WBAN) is designed to operate autonomously to connect various medical sensors and appliances located inside and outside of human body. Energy is the major concern in wearable and implantable devices in a WBAN. In order to use energy in an efficient manner a protocol is developed called as Adaptive routing protocol in which the routing strategy is based on the quality of the channel. In this approach, the source node will switch over direct and relay communication based on the quality of the link. The channel quality is determined based upon the threshold value. The analytical model is validated through simulations. This adaptive routing scheme energy consumption and certain parameters are analyzed and simulations shows that when the nodes follow adaptive routing procedure the consumption of energy is less

**Keywords:** Body area networks (BAN), Bit error rate (BER), Routing, Adaptive routing, Wireless networks.

### I. INTRODUCTION

Wireless body area network (WBAN) plays an indispensable role in emerging wireless technologies to support remote patient monitoring health care domain based on the low power semi conductor technology and radio frequency (RF) technology. A WBAN hook up individual and independent sensor nodes (e.g sensors, actuators, medical device) that consistently monitor the patient's crucial gestures, such as pulse rate, pulse oxygen level, pH level and also environmental parameters like temperature and humidity. Each user wears a number of sensor nodes that are strategically placed on the body .The patient analogous data (gathered data) from all WBANs may ultimately be sent to a centralized healthcare archive for records through a wireless personal network implemented using ZigBee (802.15.4) or Bluetooth (802.15.1). The personal server, implemented on a home personal computer, handheld computer, smart phone, or residential gateway, controls the WBAN, performs sensor fusion, and preliminary analysis of physiological data. It provides graphical or audio interface to the user, and transfers captured health information to the medical server through the Internet or mobile telephone networks (e.g., GPRS, 3G). Comparing with the current electronic patient monitoring systems WBAN overture two momentous advantages. The first advantage is the maneuverability of patients and the second one is the location independent monitoring capability. Wireless BANs consist of three standard communication protocols that sponsored by the IEEE standards committee for WSN communications IEEE 802.15.1 (Bluetooth) [1], IEEE 802.15.3 (ultra wideband, UWB) [2] and IEEE 802.15.4 (Zigbee) [3], and IEEE 802.15.6 has been developed for BANs surveillance. The purpose of this standard is to provide connectivity between low-power semiconductor sensor devices while supporting high data rates (up to 10 Mbps) as well as quality of service. The standard proposes two types of the network topologies. The first type is the star topology where each individual nodes connect directly to the central component called as hub. The second topology is the two-hop extended star topology where nodes and hub can transmit and receive the information through a relay node. To connect through the relay, the nodes and the hub encapsulate their data frames in the payload of another frame with the same type and then it transmits to the relay and then the relay retransmits the encapsulated frame to the corresponding destination.

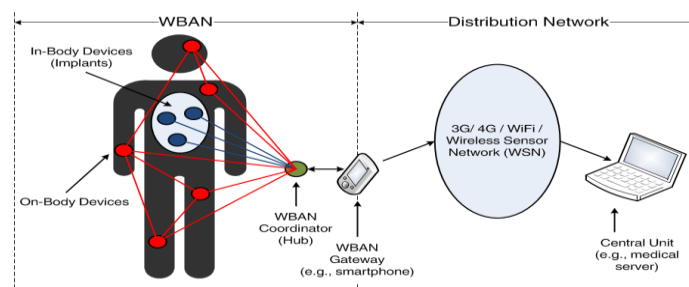


Fig 1 Illustration of WBAN

## **II. RELATED WORK**

In [4] metrics like packet delivery ratio, latency and energy consumption has been analyzed under various sampling rates. In order to control the vibrations of an automotive system IEEE 802.15.4 based sensor and actuator network has been deployed. The MAC layer controls access to the radio channel using CSMA/CA mechanism. Two operational modes are available in IEEE 802.15.4 MAC layer: the non beacon-enabled mode with unslotted CSMA/CA and the beacon-enabled mode with beacons. The parameters are analyzed under different traffic load. It is concluded that the beacon enabled mode with unslotted CSMA/CA offers high PDR and non beacon-enabled mode with beacons can provide improved latency and the energy consumption is reduced because it does not need resynchronization. In [5] BASN ( sensor network on human body) experiencing high path loss small scale networks energy consumption parameter is realized where the energy consumption or network lifetime of a single-hop network and a multi-hop network are compared. A propagation model and a radio model for exchange of information along the human body has been derived. It is calculated that single-hop communication especially for nodes far away from the sink energy efficiency is inefficient when energy efficiency is studied for star and tree topology whereas, multi-hop justifies to be more efficient. Based on these conclusions, in order to increase the network life time significantly and to overcome the performance difference a scheme is introduced by either introducing extra nodes in the network, i.e. relay , or by using a cooperative approach or by a combination of both. In [6] the current research and development on wearable bio sensors has been surveyed. Bio sensor systems are motivated by increasing health care costs and propelled by recent technologies. A variety of system implementations are compared in approach to identify the technological short comings. These systems can comprise various types of physiological sensors, transmission modules and processing capabilities. It thus facilitate low-cost wearable unobtrusive solutions for continuous all day activity status monitoring. A thorough study on the functionality and characteristics has been carried out. In scientific area and to provide development for future research improvements in scientific area and to provide development for future research improvements. In [7] the introduction of IEEE 802.15.6 communication standard optimized for low power devices in or around the human body due to lack of an appropriate wireless technology satisfies all the requirements of Wireless Body Area Networks (WBANs), the IEEE 802.15.6 Group has developed a cogent model for performance evaluation of WBAN under saturation condition and error prone channel. The back off procedure is modeled as stated in the standard employing a probabilistic approach. The results of the analytical model are compared with a simulation model and it shows that under saturation condition the medium is mostly utilized by the nodes with highest priority while other user priorities are starving.

## **III. SENSING MODEL**

Consider an example of a human body sensors located on different places in a human body. For example pulse sensor is located at the wrist, pH level sensor at the arms, pulse oximetry sensors at the chest and another body sensor (temperature sensor) is located at the foot. These sensors can exchange the information by the use of either single hop or two-hop (by using relay) to the central device. According to [18] the characteristics of the channel change by time since human body is a dynamic environment. So, using a constant scheme does not serve the purpose. So the quality of the channel is calculated by using pilot signal frequency(source) before routing the data and then routing is performed based on the channel quality. If the quality of the channel is higher than certain threshold, unnecessarily using a relay channel increases the energy cost, because the relay channel is required only in severe fading conditions. In our case, the sensor on the wrist occasionally experiences high quality link with the hub and hence using a direct path is more energy efficient than using relay path. On the other hand, during the hand movements, the link quality may suffer severe fading due to the blocking by the human body and hence using the relay path would be inevitable.

### **3.1 Pulse Sensor**

The required components are IR LED (Infrared light emitting diode), Photo diode which serves as the sensing device. The IR LED transmits an infrared light into the fingertip, a part of which is reflected back from the blood inside the finger arteries. The photo diode senses the portion of the light that is reflected back. Whenever the heart pumps blood more light is absorbed by increased blood cells and we will observe a decrease in the intensity of light received on the LDR. As a result the resistance value of the LDR increases. This variation in resistance is converted into voltage variation using a signal conditioning circuit usually an OP-AMP. The signal is amplified enough to be detectable by the microcontroller inputs. The microcontroller can be programmed to receive an interrupt for every pulse detected and count the number of interrupts or pulses in a minute. The count value of pulses per minute will give you the Heart rate in bpm (Beats Per Minute).

### **3.2 Pulse Oximetry Sensor**

Oxygen saturation level can be measured using pulse oximeter. A Pulse oximetry uses light to work out oxygen saturation. Light is emitted from light sources which goes across the pulse oximeter probe and reaches the light detector. Pulse-oximeter uses two wavelengths of light, typically at 660nm (red) and 950nm (infrared) to determine the colour and hence oxygen saturation of arterial blood. Reduced haemoglobin and oxyhaemoglobin have different absorption coefficients at different wavelengths of light. It can be seen that the lines cross over at about 805nm, the isobestic point. What this means is that above 805 nm oxyhaemoglobin absorbs more light than reduced haemoglobin and below 805nm reduced haemoglobin absorbs more light than oxyhaemoglobin. Because of this fact and by using two wavelengths of light the actual oxygen saturation level can be determined.

The fundamental pulse oximetry Ratio of Ratios concept was invented and further refined by and Dual-wavelength illumination of arterial blood results in an absorption contrast that depends upon the proportion of hemoglobin that is chemically combined with oxygen. The color of blood varies depending on the oxygen content and in particular the hemoglobin molecules reflect more red light when they are oxygenated, whereas, the reflection of infra-red light increases with de-oxygenated hemoglobin molecules. Hemoglobin bound to oxygen is called oxygenated hemoglobin (HbO<sub>2</sub>). Hemoglobin not bound to oxygen is called deoxygenated hemoglobin (Hb).

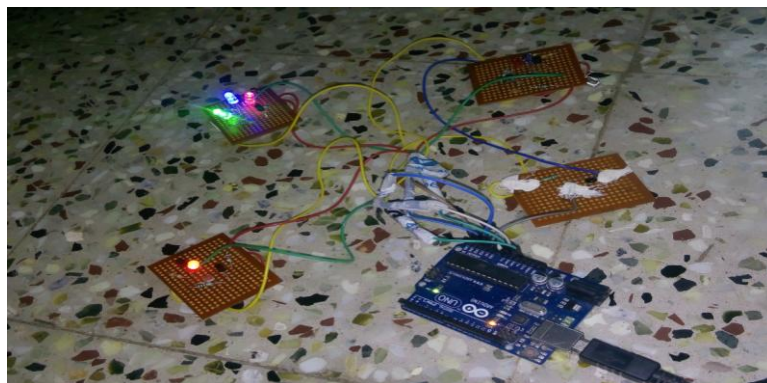
### **3.3. Temperature sensor**

Temperature of a human body (skin temperature) can be measured using a thermistor. A thermistor is a component that has a resistance that changes with temperature. There are two types of thermistor. Those with a resistance that increase with temperature (Positive Temperature Coefficient – PTC) and those with a resistance that falls with temperature (Negative Temperature Coefficient – NTC). When temperature changes, the resistance of the thermistor changes in a predictable way. The analog output is obtained based on the temperature measured.

### **3.4 pH sensor**

The Ph Value of human blood is measured by using The LDR color sensor, this sensor having three colors LED's. These three colors red, green and blue (RGB) color model. These three LED's connected with the Light dependent Resistor (LDR). Shown in fig 9. The LDR is connected with an appropriate resistance, so as to divide the reference voltage (5V) between itself and the fixed resistor. As the light intensity varies so does the voltage across the LDR. The key idea is to record the voltage across the LDR when the object is illuminated by one of the three colors. Human blood stays in a very narrow pH range right around (7.35 - 7.45). Below or above this range means symptoms and disease. If blood pH moves to much below 6.8 or above 7.8, cells stop functioning and the patient dies. The ideal pH for blood is 7.4[21]. A healthy blood pH without cancer has acid + alkaline balance almost equal. Actually a healthy body is slightly alkaline measuring approximately 7.4. This ideal blood 7.4 pH measurement means it is just slightly more alkaline than acid.

The readings are transferred through serial port and it is read by MATLAB.



**Fig 2** Final Hardware set up

## **IV. CHANNEL QUALITY**

The channel quality is calculated through the pilot signal. A pilot frequency is a single frequency transmitted over a communication channel for equalization or synchronisation. The channel quality is calculated over various scenarios. Fig 3 and 4 indicates the BER vs SNR graph obtained through MATLAB simulation. These graph clearly indicates that when a hub is placed at a distance of 4 meters then the Bit error rate (BER)

increases hence using relay for routing will be an optimal solution and when the hub is placed at a distance of 1 meter using single hop proves to be a good solution.

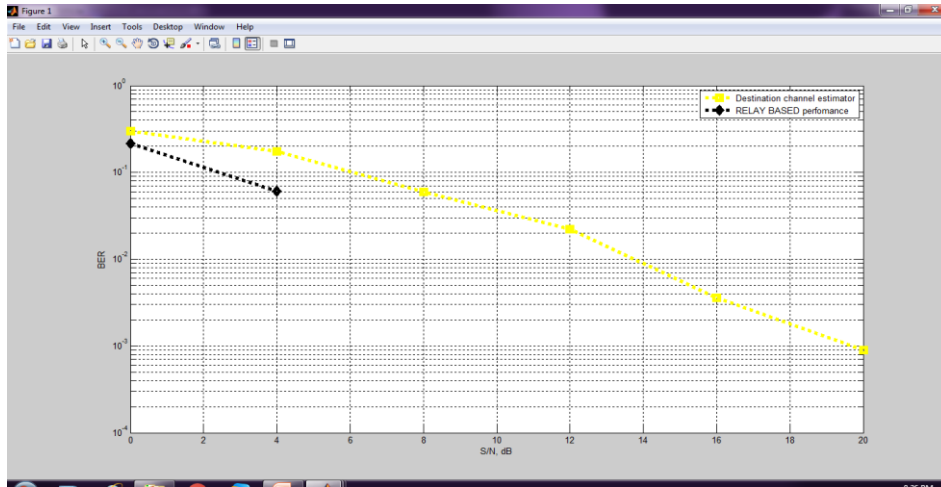


Fig 3 When destination (hub) is at 1 meter

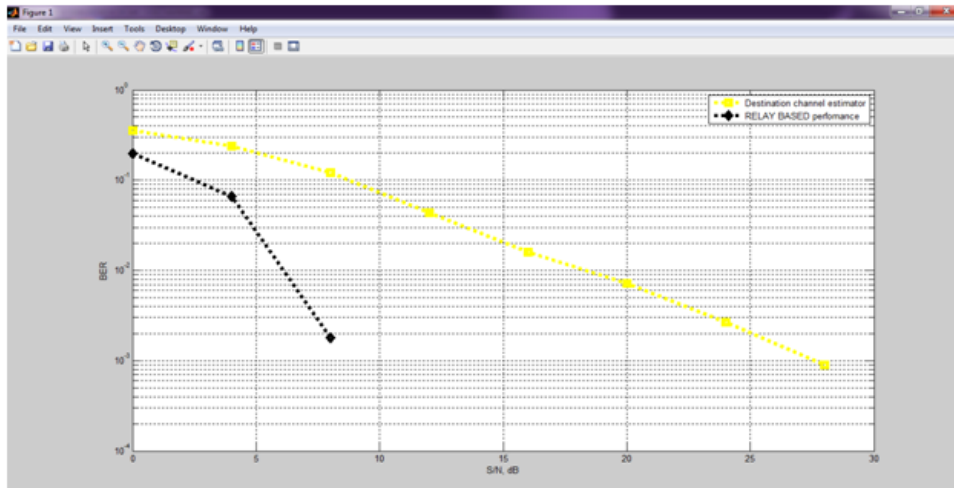


Fig 4 When the destination (hub) is at 4 metres

## V. SIMULATION RESULTS

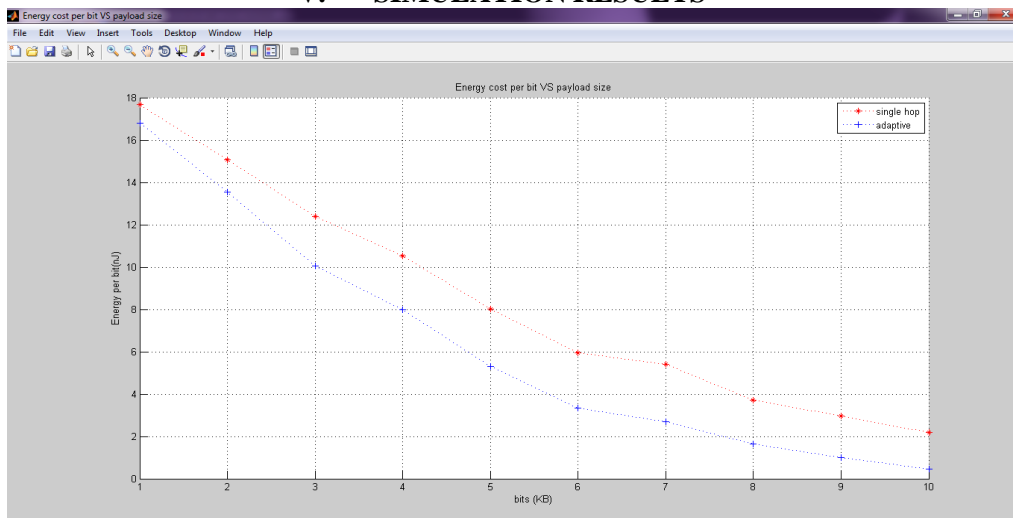


Fig 5 Energy cost Vs Payload

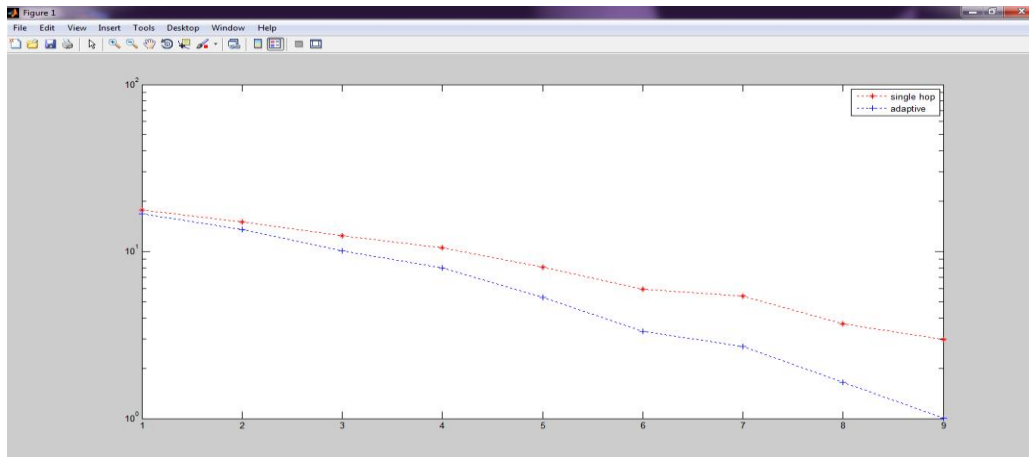


Fig 6 Error probability Vs Number of retries

From Fig 5 it is inferred that the energy cost for transmitting a bit of information is reduced for an adaptive routing when compared to that of single hop. Fig 6 concludes that for the maximum number of retries the error probability is reduced and the error probability is very much reduced for adaptive routing compared to that for single hop routing.

## VI. CONCLUSION

The energy consumption is addressed in a wireless body area network. An adaptive scheme is proposed to improve the energy efficiency of the nodes in the network. The key idea is to adaptively change the routing strategy based on the quality of the channel. The adaptive protocol is mathematically analyzed and simulation results show that adaptive routing involves less energy consumption compared to single hop routing.

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