Comparison of Energy Harvesting Techniques in Wireless Body Area Network

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***Abstract*– Wireless body area network is very significant topic now a days and it is developing technology in the field off human body health services because it's developing time to time and play very important role to improve human health. In this paper, we conduct a survey of WBAN harvesting techniques and discuss the different challenges and issues that are involved in the design of WBAN. Batteries are the main element of sensor nodes which use power to work properly that's why management of power resource is the main challenge. To overcome this challenge use Past research describe the different types of harvesting techniques such as Vibration, solar, blood pressure, thermal, wind and radio frequency harvesting technique. We explore the thermoelectric generators for energy harvesting from the human body using the thermal harvesting technique and compare all the harvesting techniques which one is produce mover power for the nodes and suitable for the different environmental conditions. At the end we also discus about the different applications of WBAN that are used to improve human health.**

***Keywords*– Wireless Body Area Network (WBAN), Wireless Local Area Networks (WLAN), Electrooculography (EOG), Electromyography (EMG), Electrocardiography (ECG), Electroencephalography (EEG), Energy Harvesting (EH), Radio Frequency (RF) and Radio Frequency Energy Harvesting (RFEH)**

I. INTRODUCTION

The wireless body area network (WBAN) is very hot topic now days to monitor the health and movements of a patient using sensor nodes placed in or around the body. Sensors nodes are planted in the body tissue of the body are shown in Fig. 1. The main role of sensor nodes to send collected data to the main servers for evaluation of health of the patient and send collected data to the back end servers are that are connected with Wireless Local area networks (WLAN). Different types of signal are transmit from the nodes such as electrooculography (EOG), electromyography (EMG), electrocardiography (ECG), electroencephalography (EEG) also sense the temperature and conductance of the skin.

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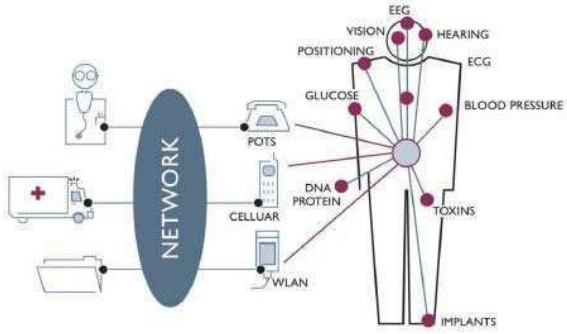

Fig. 1. Wireless Body Sensor Network Model

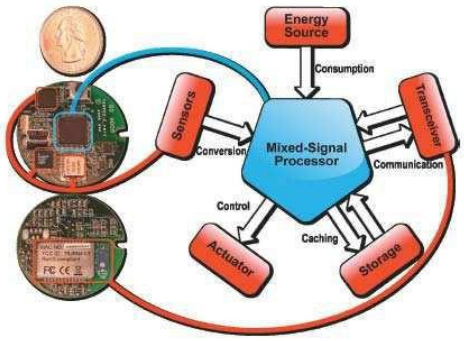

Fig. 2. WABNs node architecture

Function of sensors is to measure the different parameters of the body in different time places and send this data to actuators. These actuators send this data on the servers using WAN or different mediums [2]. During design sensor nodes WBAN we face different challenges such as weight of nodes, performance; most important is long battery life because nodes are powered with the battery. Also use different techniques to charges these batteries using different technologies [3]. Now a day's most of the research is to increase the battery timing and energy harvesting with low

power consumption. The entire component of the sensor node takes power to work perfectly such as transmitters, receivers, sensors, data controller and micro-controller [4]. The main focus is to reduce power consumption with the different methods commonly used method is to reduce power consumption is to adjust duty cycle of a censor node if sensors are adjust to operate on 1 percent of duty cycle alternately full cycle. Due to this adjustment power consumption reduce to 0.3 mA from 30 mA [5]. Furthermore, the main issue faced in WBANs to recharge or change the batteries regularly. To overcome these issues energy harvesting methods are used for long time battery power without recharge the batteries. These techniques use body heat, light and the movement of the body to enhance the battery time of the sensor nodes. Our main focus is to find the energy harvesting techniques that increase power of the sensor nodes from the human body movements and the circulation of blood.

In [6] authors explain the different techniques of the energy harvesting techniques. Authors proposed stationary and generalized models that extract the harvested-energy. In [7] and [8] are also present the energy harvesting techniques using the previously proposed models they combine these models for get better results in energy harvesting and data traffic. Power consumed by the sensor nodes is divided into different functions that can performed by the node. Many authors describe the architecture of the nodes time by time [9]. Elements of the sensor nodes with the energy harvesting technique are shown in Fig. 3 all the elements of the node are presented in the figure. Element of the nodes are not same for the entire sensor node. Elements of the sensor nodes take power with respect to their usage it's very difficult to find that which part of the node take more power. Specification of WBAN is given in the Table I.

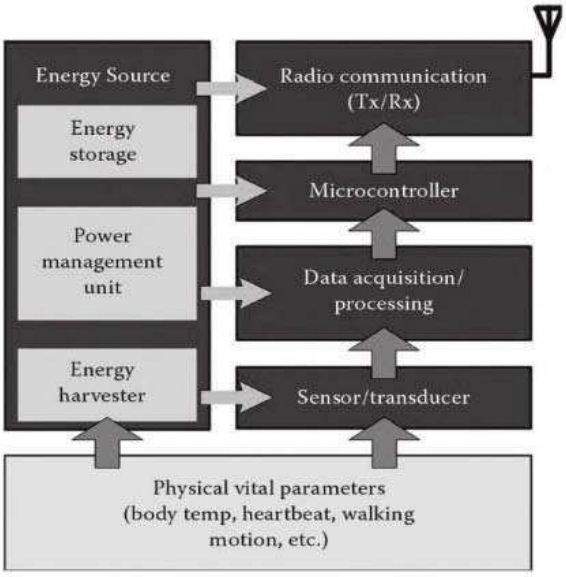

Fig. 3. Block Diagram Sensor Network Node

Table I: Specification of WBAN

Attribute	Value
Distance	2 meter stander 5 meter special case
Start up time	< 100 ns
Network Setup time	<1 sec / device
Power consumption	~ 1mW/Mbps
Network density	2-4 Nets / m^2
Latency (end to end)	10 ms
Network size	Max 100 devices /Network

Table II: Energy Harvesting Sources

Energy Source	Conditions	Performance
Solar	Outdoors	7500 μW/ cm^2
Solar	Indoors	100 μW/ cm^2
Vibration	1m/s^2	100 μW/ cm^3
RF	WiFi	0.001 μW/ cm^2
RF	GSM	0.1 μW/ cm^2
Thermal	ΔT = 5 °C	60μW/ cm^2

II. ENERGY HARVESTING TECHNIQUES FOR WBAN

In wireless body area sensor networks we need to recharge sensor nodes to work perfectly with in the human body different types of energy harvesting techniques are used to recharge sensor nodes to work perfectly. There are different types of harvesting techniques that can charged the sensor nodes such as from sun light, thermal energy, radio frequency, blood pressure, body movement and vibration, also charged through body heat, etc. These harvesting techniques are used to recharge the sensor nodes; they reduce the need of battery in WBAN and devices that consume energy they can easily work on harvesting energy directly received from the ambient source. In this paper, we elaborate the different types of harvesting techniques and below in Table III, we describe the different EH techniques with respect to their energy sources.

Table III: EH Techniques with respect to their Harvesting Sources

Energy source	Nature of source	Transducer
Thermal	Fully controllable	Thermoelectric element
Mechanical	Uncontrollable and unpredictable	Piezoelectric transducer
Solar energy	Uncontrolled but predictable	Photovoltaic cell
RF energy	Partially controllable	Antenna

A) Solar Energy Harvesting

Sensor nodes have multiple elements such as energy harvesting unit, storage module such as super-capacitor, Sensing- element, micro-controller and a transmitter. All the elements are shown in Table II. Solar energy generates much power that is enough for the usage of sensor nodes. Solar energy is used as an energy harvesting for sensor nodes

and its directly provide dc current to the nodes to recharge. Solar panel harvested 100MW electrical energy and power drops indoor due to environmental changes. Different models for solar harvesting techniques are proposed by different authors, in which the energy devices precisely connected with the storage device. In solar harvesting its compulsory to use solar energy harvesting device t convert the light to electrical current point and control the maximum power-point. Lot of researchers working on solar energy harvesting technique to make the sensors more perfect to work perfectly. The disadvantage of this technique during the time when energy not harvested due to this issue face power drop rapidly [3].

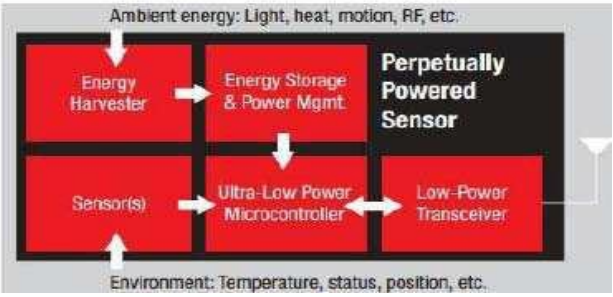

Fig. 4. Wireless Body Sensor Node Elements

B) Vibration Energy Harvesting

Mechanical vibration is an ideal way to get an energy source and its very easily available everywhere such as buildings, transportation, human actions, industrial activities, devices is used in military etc. In vibration energy harvesting technique vibrations are used to charge the sensor nodes and the power of energy that can be gain from the vibration is round about 300. There are three types off devices that can convert mechanical energy to electrical energy are electromagnetic converter, piezoelectric and electrostatic converter. This energy used to recharge the sensor nodes in WBAN .In previous researchers find that the human walking also a source of producing energy by putting a piezoelectric Powered system in shoes during walking. Its produce more than 10mW energy during the walking in normal conditions [10]. Later on more work done by researcher on VEH using the micro generators and its produce 4micro watt, during human body movement and increased up to round about 800 micro W, with the help of stimuli machine induced [11].

C) Thermal Energy Harvesting

Thermal Energy is a way to produce thermal energy and after that converts it into electric current using the different techniques. Thermo electric generator (TEG) devices are the most popular example of TEH devices. The commercial example of TEG is thermic-watch that was introduces by Seiko and its working on heat that produced from human body. Architecture of TEG watch is shown in figure below. The maximum power that can generate by the TEG devices is 1-60 micro watt per cm square in the 5 K temperature [12]. At the other end researchers briefly describe that the TEH using the thermo-electric conversion are very different in different environmental conditions such as air and ground. Later on TEH systems placed in the green-house using solar thermal energy harvesting system and use the TEG devices to recharge the battery. Its produced roundabout delta T of 25 K energy that can recharge 80 mAh battery in very short time [13]. The thermo generators that are communally available need 10-200 degree C to generate thermal energy ,due to different weather conditions its very to produce thermal energy in en-closed environments [14].

D) Radio Frequency Energy Harvesting

Radio Frequency EH systems are get power from the Base stations, Wireless Network, Television towers. RFEH systems received Direct current that is used to charge the sensor nodes circuits. This system received electromagnetic waves through the antennas and converts these waves into DC voltage. The RF energy harvesting is used to charge sensor nodes through wireless charring [15]. Architecture of RFEH system is shown in fig below its used transmitter to get energy from the radio waves, the advantage of this techniques that the amount of harvested energy is controlled to adjust the requirements of energy with respect to time intervals. In RFEH systems according to equation that is introduced by the Friis their power that is collected through the antenna is high in power then the energy is converted into the DC voltage [16].

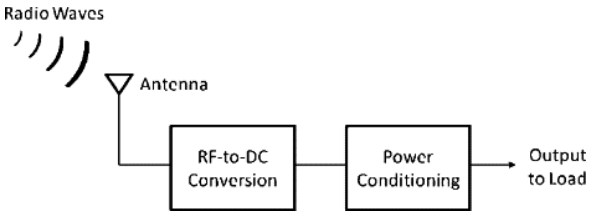

Fig. 5. RF EH architecture

E) Blood Pressure Energy Harvesting

Blood pressure of human body is also used for energy harvesting using certain fabric that is only use for the person who wears it to generate harness-energy. Heart beats of a normal person is 60 beats in one minute and the volume of a heart stroke is 70ml, a normal human can generate 0.93W using its heart beat [17]. When blood pressure measured through a piezoelectric generator then power generates in micro-watts and when the battery going to charges the power continuously changes to mill watts. Harvesting energy produce through blood pressure using the wearable micro sensors [18].

III. COMPARISON OF ENERGY HARVESTING TECHNIQUES

In Table IV various type of energy harvesting techniques are listed with respect to their power density. Below Table IV shows the each EH technique with respect to their Power generation, with the help of these observations we observe

that there is no rare solution for all of these techniques. In below listed techniques solar energy technique generate more power than the all techniques but it's not for the continuous time because indoor its decrease tremendously. Other sources are also provide high power but its depend on their specific area with respect to their applications such as in sunny day give huge amount of solar energy and a bridge structure give strong vibration during vehicle traveling etc.

Table IV: Comparison of Energy Harvesting Techniques

Energy Source	Performance	Notes
Ambient light	100 mW/cm² (direct sunlight) 100 μW/cm² (illuminated office)	Common polycrystalline solar cells are 16–17% efficient, while standard monocrystalline cells approach 20%
Thermal	a) 60 μW/cm² at 5 K gradient b) 135 μW/cm² at 10 K gradient	Typical efficiency of thermoelectric generators is ≤ 1% for ΔT < 313 K a) Seiko Thermic wristwatch at 5 K body heat b) Quoted for a ThermoLife® generator
Blood pressure	0.93 W at 100 mmHg	When coupled with piezoelectric generators, the power that can be generated is on the order of microwatts when loaded continuously and milliwatts when loaded intermittently
Vibration	4 μW/cm³ (human motion-Hz) 800 μW/cm³ (machines-kHz)	Predictions for 1 cm³ generators. Highly dependent on excitation (power tends to be proportional to ω, the driving frequency, and y_o, the input displacement
Ambient radio frequency	<1 μW/cm²	Unless near a radio frequency transmitter

IV. APPLICATIONS OF WBAN

WBAN is used for many treatments and diagnose the disease in the human body. Lot of researchers doing work on WBAN applications. Some diseases are discussed in Table V.

Table V: WBAN in Human Health Care

Field of application/Disease	Sensors,	Role of WBAN
Cardiovascular Disease (CVD) 30% of all global deaths 17.5 million Deaths per year, 2015, expected 20 million patients. [19]	Pulse oxi-meter Heart rate sensor ECG sensor	The corresponding medical staff can do treatment preparation in advance as they receive vital information regarding heart rate and irregularities of the heart while monitoring the health status of the patient. [20],[21]
Post operative monitoring	Temperature sensor, blood pressure sensor, Heart rate sensor, ECG	the patient will no longer need to stay in bed, but will be able to move around freely
High Blood pressure High blood pressure contributes to more than 12.7 million strokes worldwide. [22]	Blood pressure sensor Actuator with medicine	If the sensor monitors a change in blood pressure more then threshold value, a signal can be sent to the actuator in order to start the injection medicine. Consequently, there are lesser chance of strokes
Pain treatment	Actuator with pain killer	Actuator is a spinal cord Stimulator implanted in the body for long-term pain relief.

Lot of people from all over the world is died due to accidents due to human-errors. With the help of sensor it's very easy to maintain a record of person about their previously accidents, we can rectify the same accident through sensors and reduce lot of accidents. Using the WBAN professional athletes are train them self-more efficiently to achieve their fitness level.

WBAN is used to identify the hospital before the heart attack using the sensor nodes that are used in the human body for sensing. WBAN also detect the insulin level of a patient who is suffering from the diabetic disorder .WBAN automatically inject a insulin through a pump when insulin level decreased.

WBAN is also used by armed forces to detect the toxic level in the air and warn the soldiers about the level of life threatening.

In Table V there are some applications of WBAN with respect to their technologies requirements.

Table VI: WBAN Applications

Application	Examples	QoS Requirements				Technologies used
		Reliability	Latency	Security	Power consumption	
Telemedecine	Remote Health monitoring	*	*			Bluetooth
	Emergency rescue	*	*		*	IEEE 802.15.6
	Chronic diseases monitoring	*	*	*	*	ZigBee
	Prevention and detection of diseases	*		*		WiFi
	Daily-life activity monitoring		*	*	*	RFID
	Post-surgery in-home recovery monitoring	*	*			ANT
Rehabilitation	Daily life and rehabilitation	*	*		*	ZigBee WiFi
Assisted living	Assisted living for elders	*	*	*		IEEE 802.15.6
	Treatments of peoples at home	*	*	*		ZigBee
Biofeedback	User biofeedback activity	*			*	ANT Bluetooth ZigBee

V. OBJECTIONS AND ISSUES IN WBAN WBAN

WBAN is very developing technology nowadays but there are many issue still persist in this technology that need more improvements .WBAN face technical and ethical both types of issues such that privacy is most critical ethical issue and some technical issues are shown in Table VII.

VI. CONCLUSIONS

The goal of this paper was to describe the importance of WBAN in human life and how can it used to improve human health. In this paper, we describe the different approaches of energy harvesting and power management with the help of different ambient sources such as solar, wind, thermal, vibration, RF and blood pressure. Also compare the harvesting techniques with respect to power generations and explain these techniques with the help of TABLE IV. We also try to explain the application of WBAN that are used in our daily life such as Health care for athlete's training, remote health monitoring, emergency-rescue, used by armed forces etc. In future we will study the thermal energy harvesting techniques and find that how we use the thermal harvesting for the detection of axious gases in the operation that are done by the armed forces in a critical situation.

Table VII: WBAN Applications

Node Tasks	Node performs multiple tasks
Node Size	Small is essential low on complexity, light in weight, power efficient, easy to use and reconfigurable, storage devices need to facilitate remotely
Network Topology	More variable due to body movement
Power Supply	Inaccessible and difficult to replaced in an implantable setting
Power Demand	Likely to be lower, energy supply more difficult
Energy Scavenging Source	Most likely motion (vibration) and thermal (body heat)
Architecture	Sensor, Actuator and central unit communicate through PDA

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