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Ambient Backscattering for Efficient Battery-less Wireless Body Area Networks as used in Telemedicine for Remote Patient Monitoring

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Abstract - Ambient Backscattering (AB) is an emerging technology that can be used to replace small battery powered devices. It works by utilizing the existing ambient signals to harvest energy and propagate its own signal. In this paper, the aim is to propose using AB in Wireless Body Area Networks (WBAN). WBANs mainly consist of sensors that can be attached on or implanted into the human body, enabling greater mobility of patients and improving Quality of Life. The sensors record patient vitals, that can be transmitted to a central hub for monitoring. The recorded patient vitals can then be analyzed by doctors remotely. Telemedicine has enabled physician and patient interaction and consultation without being physically present at the same place. The growth of Wireless Sensor Nodes is limited by high cost and energy consumption and AB has the potential to overcome these limitations. Elimination of the RF transmitter will reduce the size and elimination of the battery will increase the life of the sensor devices, improving overall efficiency of the system.

Keywords - *Ambient Backscatter (AB), Wireless Body Area Networks (WBAN), Sensor Networks, Remote Patient Monitoring (RPM), Telemedicine.*

1. Introduction

The introduction of IoT devices and wireless communication, has caused a drastic increase in the number of wireless devices and radio waves in the environment. With numerous devices being connected to the internet, many challenges crop up. The most obvious one being the obstacle posed by the short lifecycle of the sensor devices, needing constant replacement. In order to make optimal use of the frequency spectrum and to extend the life of sensor devices, we need to reuse the already generated radio waves. This is where the ambient backscatter technology comes into play. These AB devices use the existing radio frequency signals (such as radio, TV, Wi-Fi and cellular mobile) to transmit data without a battery or power connection. When an ambient radio wave is incident on the antenna of a backscatter device, it either absorbs or reflects the signal. The device communicates its message in the form of bits, by switching its antenna to reflecting and non-reflecting state. This will solve the battery crunch issues these devices currently face [8].

Body Area Networks (BANs) have attracted a lot of attention in the significant role that it can play in medical usage and personal health tracking. The monitoring of patient vitals in hospitals are a major contribution of BANs. The drawback being the limited mobility of the patient by confining them to a bed, making them uncomfortable. This type of monitoring prolongs the duration of hospitalization and in turn, increases the cost. Keeping this in mind, Wireless Body Area Networks (WBANs) were introduced. WBANs helped in providing greater mobility to the patients and making remote monitoring a reality. With such advancement in technology, Telemedicine and Remote Patient Monitoring came to the forefront. Telemedicine has enabled physician and patient interaction and consultation without both parties being physically present at the same place i.e. consultations take place outside of a traditional clinical setting with the help of technologies like video conferencing. This is an excellent way of monitoring an infectious disease and puts the patient, doctor or any supporting member at zero risk of spreading or contracting any disease.

There are two categories of sensors used in WBANs, one that is implanted into the human body and another that is mounted on the surface of the body in a specific fixed position, for accurate reading. The sensors record patient vitals, that can be transmitted to a central hub for

monitoring. The recorded patient vitals can then be analyzed by doctors remotely. It can also be continuously analyzed by a tool, that has been trained using a machine learning algorithm to catch any abnormalities in the readings and then referred to a physician. Help could be given to patients much sooner, as any anomalies in the readings would raise alarms [9]. Improved response time leads to better care. WBANs also have other applications such as use in military rescue operations, where the soldier is wearing sensors that allows him to be tracked and monitoring his vitals will show if he has been injured and requires any help. [6]

Introduction of Ambient Backscatter technology into the architecture of WBANs would make a huge difference. WBANs improved the mobility of the patients, but the battery life of these sensors was short and soon would need replacement. The battery also makes the sensors heavier and bulkier. This becomes a problem with sensors that must be implanted into the body. With AB technology this can be a non-invasive procedure after the first implant, since it would make the device battery-less and no replacement is needed. With the non-existence of a battery it also eliminates the risk of the toxic battery fluid leaking into the body cavity of the patient. As for the wearable devices, they are most used as a personal choice that people can use for health and fitness tracking in the form of wrist bands, but there are other varieties also available that are physician recommended and used for medical monitoring. Surface mounted sensors do not involve any risks, but with the use of AB the device life will be extended and need not be recharged or replaced periodically, resulting in continuous monitoring and data generation. What can also be noted from continuous data generation is learning what sequence of symptoms leads to a certain condition or how a patient's body reacts to a treatment etc. Extensive studies can be carried out with such data and this ensures decisions are made on the best possible information. [3,7]

There is an explosive growth in the number of sensing devices that need to be connected to the Internet via wireless links. Wireless Body Area Network devices fall under this category. As indicated in [1], such massive connectivity requirements must cope with two main limitations: the scarcity of dedicated spectrum portions to allocate sensor transmissions, and the need to reduce, if not eliminate, the communication dependence on batteries. With this said, Ambient Backscatter can be the key enabling technology for extensive sensor networks. Ambient radio waves can be reused as a source to backscatter the data to a receiver, eliminating the need for dedicated RF transmitters [4], since they do not have to produce their own radio waves. Also, a part of the incident RF wave is used to harvest energy by the device in order to carry out internal circuit operations. The amount of energy harvested with AB is in a few milli Watts and is enough to power itself and carry out the required operations and sensor functionality [2]. Elimination of the RF transmitter and battery makes the device more light-weight, small and less expensive to manufacture, as all components are easily available.

Improved response time to patient needs by detecting anomalies in the generated data at an early stage, increased quality of life of the patient, short or no hospital visits and reduction in overall cost are all possible with WBANs. AB technology making the sensor devices battery-less overcomes the energy constraint obstacle of the sensor devices. Elimination of the RF transmitter makes the devices smaller, lighter and less-expensive. The addition of Ambient Backscatter technology into the sensor hardware can make Remote Patient Monitoring very efficient opening up new possibilities in the health care sector.

2. Proposed Architecture

With the advancement of computer networks people can do a lot of things from the comfort of their homes. The internet has provided us the privilege to connect with our loved ones halfway across the world, have groceries and supplies delivered to our doorstep and even conduct and attend online classes. So why not consult doctors from home? The next immediate question that arises is- how will the doctors examine you? This can be taken care of by the WBANs. The sensors that make up the WBAN are connected to the appropriate body parts based on what vitals need to be monitored (explained in the next section). The more sensors your tracker has, the more accurate its data. As shown in fig1, Consolidation of data from all sensors can be done on the personal patient monitor, where the patient also can view these vitals to make appropriate changes to diet and lifestyle in order to maintain the levels as advised by the doctor. All this data is then dumped onto the cloud that contains the database of the patient's information.

On the cloud we can run various machine learning algorithms on this data, at regular intervals, to find any anomalies or underlying health conditions and raise alarms at an early stage. The patient, doctor and the caregiver can view the data on the cloud and take the necessary steps. In case of any emergencies the ERT can use this information

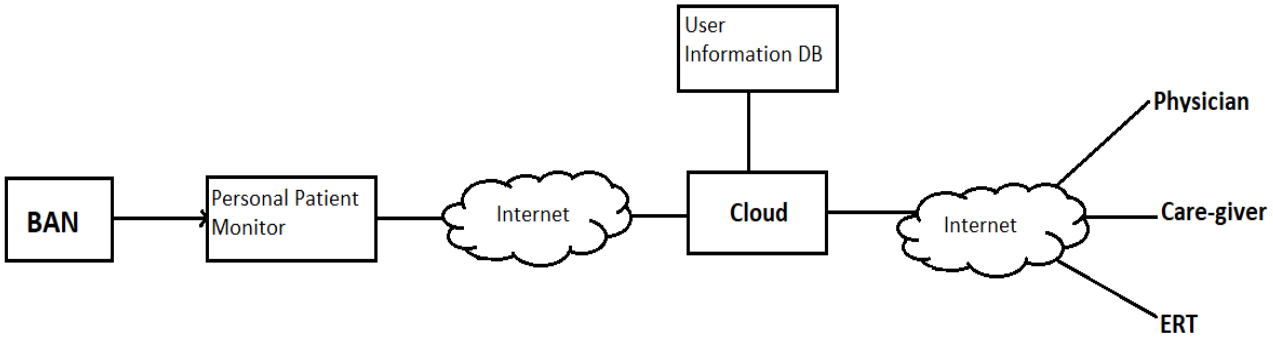

Fig. 1: End to End connectivity

to provide better care. The user database can contain information like the medication the patient is under, the health conditions and diagnosis made by the physician, the consolidated data from the sensors and all patient history (like appointments and treatments, allergies, etc.), which all contributes to better and more personalized care. [5,6]

3. State of the Art

The sensors being the most important part of this whole system, need to fetch accurate readings, must be small, lightweight and have a long life. Ambient backscatter technology aids the reduction in size by eliminating the RF transmitter and elimination of the battery, which will also increase the life of these sensors infinitely and require maintenance and/or replacement, only due to wear and tear. Some of the sensors and devices that can benefit from Ambient Backscatter technology are as follows

The different types of sensors and devices, their use, placement on the body, approximate cost in India and power consumption is given below:

3.1 Accelerometer

As the name suggests, it is a device used to measure the forces of acceleration exerted on it. The forces may be static, like the continuous force of gravity or, as is the case with many mobile devices, dynamic to sense motion or vibrations. This is used in BANs to measure the physical activity, like running, walking, etc. done by the wearer. As shown in fig2, the sensors are most usually placed on the wrist, i.e. in the smart fitness band the user may be wearing or can even be strapped to the ankles. A 3-axis accelerometer that tracks movement in all directions is used in such devices. These days most smart phones come with an in-built accelerometer. The MEMS accelerometer costs between rupees 150 to rupees 800 in India, depending on the variant. Power consumption is around 4 micro Amps [13, 18].

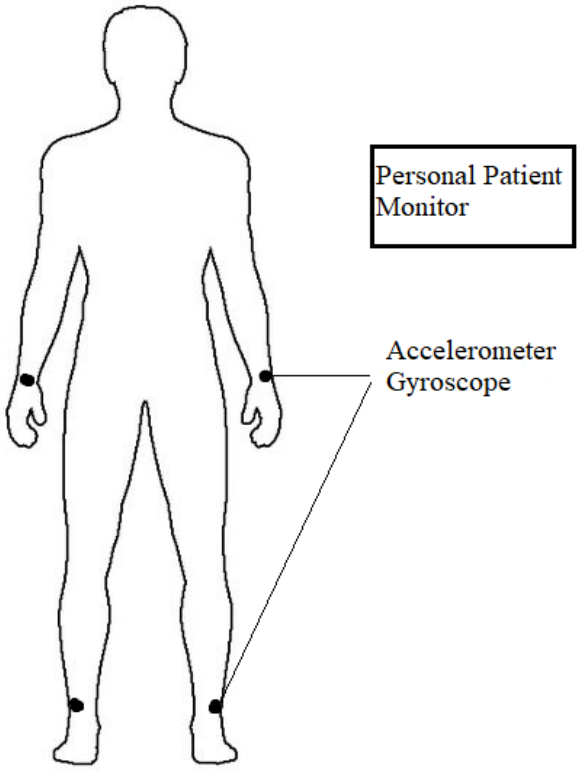

Fig. 2: placement of accelerometer and gyroscope sensors

3.2 Gyroscope

Gyroscope sensor is a device that can measure and maintain the orientation and angular velocity (rotational motion) of an object, measured in degrees per second or revolutions per second. Gyroscopes are more advanced than accelerometers as it can measure the tilt and lateral

orientation of the object whereas accelerometer can only measure the linear motion. Gyroscopes are used in BANs to know if a person has had a fall, or to measure the movements in a sport, etc. Like accelerometers, gyroscopes have the same placement on the body, shown in fig2. The cost of these sensors in India can range from rupees 200 and go up to a few thousands. Power consumption is 850 micro Amps [14, 19].

3.3 Temperature sensor

Temperature sensor is a device used to measure the amount of heat energy or even coldness that is generated by an object or a system, allowing us to "sense" or detect any physical change in temperature. A temperature sensor consists of two basic physical types: Contact Temperature Sensor and Non-contact Temperature Sensor [15]. The most obvious use being to test if the person is running a fever. It is also used in fitness bands to track intensity of the workout, the more the body is heated, better the workout. They can be placed anywhere on the body depending on the sensor. Temperature sensors cost anywhere between rupees 50 to rupees 1500 in India. Power consumption is around 20 micro Amps [20].

3.4 Altimeter

It is a sensor used to measure the altitude. It is most useful for mountain climbers, but it is also used to track the number of times the user has climbed and descended a flight of stairs. The placement of the sensor is on the wrist as its used in fitness bands. Power consumption is around 40 micro Amps.

3.5 Pulse/heartrate sensor

As the name suggests, it is a device used to measure the pulse or the heartrate of the user. The sensor makes use of a light emitting diode and the change in the light intensity reflected back is used to calculate the blood flow and hence the heartrate. This sensor can be placed on the wrist, neck or chest, as shown in fig3. Placing it on the chest gives more accurate readings. The prices range between rupees 150 to rupees 500. Power consumption for this sensor is around 4 mA [21].

3.6 Pressure sensor

Blood Pressure (BP) is one of the most important vital signs. It is the pressure exerted by the circulating blood on the walls of blood vessels. Blood Pressure is expressed as the ratio of the systolic pressure (as the heart beats) over diastolic pressure (as the heart relaxes between beats). In automatic Blood Pressure measurement system, instead of mercury a pressure sensor is used to detect the pressure in the artery and give output. Using Oscillometric techniques this Sensor can measure systolic, diastolic, and mean arterial pressure. It can also measure the pulse rate. This sensor is placed on the finger or wrist and costs about 500 to 1000 rupees. Power consumption is 5 mA [16, 28].

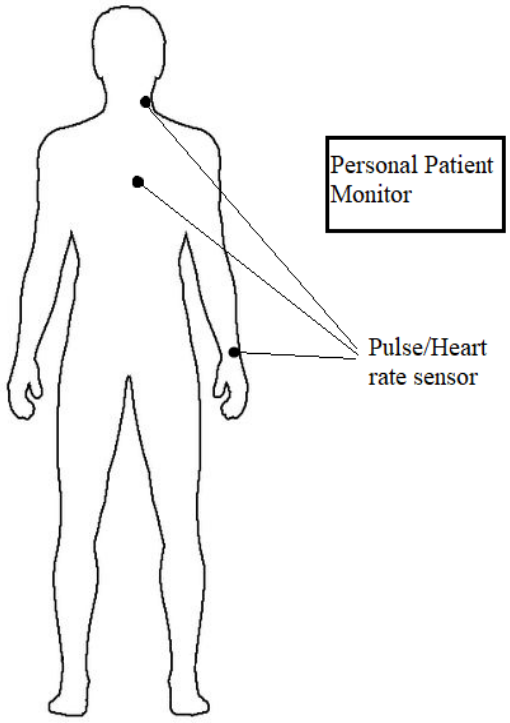

Fig. 3: placement of the pulse/heartrate sensor

3.7 ECG (electrocardiogram)

Miniature electrodes are placed on the persons chest and based on the electrical signals generated by the heart and blood flow the vitals are taken. ECG sensor is used to detect if there are any abnormalities in the heart function, if the heart beats too fast, too slow, or irregular beating pattern. The sensors are placed on the chest, they can calculate heart rate and blood pressure as well. They cost between 850 to 3000 rupees and use around 15 mA of power [22, 29].

3.8 EEG (electroencephalogram)

Like how the ECG measures electrical signal generated by the heart, an EEG measures the electrical activity of the brain. EEG scans are performed by placing EEG sensors – small metal discs also called EEG electrodes – on your scalp, as shown in fig4, which pick up and record the

electrical activity in your brain. They cost around 8000 to 10000 rupees and consume power up to 15 mA [17].

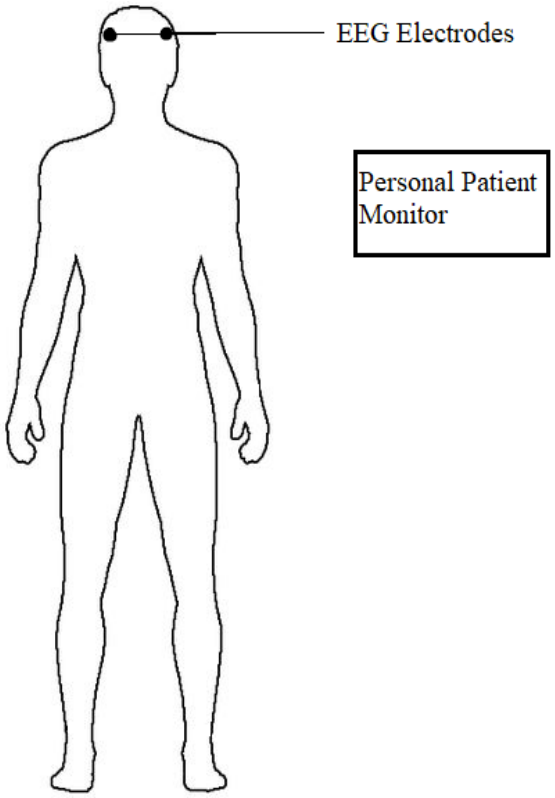

Fig. 4: Placement of EEG electrodes

3.9 Bioimpedance sensor

Like ECG and EEG, bioimpedance also uses electrical signals capturing a wide range of physiological signals. It makes use of four electrodes, two outer electrodes to produce small electric current and two inner electrodes to pick up these changes. Bioimpedance targets body tissue and is used to measure body composition, such as body fat with respect to your lean body mass [21]. Can be placed anywhere on the body, some fitness trackers and BMI calculators require you to hold the electrodes in your palms. Power consumption is 15 mA.

3.10 CGMS (Continuous Glucose Monitoring System)

Continuous glucose monitoring systems are used to track the real time data about glucose levels in the body and this data is sent to the personal patient monitor where the user can see the changes and variations in glucose levels. The glucose sensor and transmitter are implanted on the abdomen or on the triceps area of the arm, as shown in fig5. This can be used only to monitor glucose levels or attached to an insulin pump to regulate the glucose levels as well. The sensor needs to be replaced every 3 to 10 days depending on the model and the transmitter every 3 months. CGMS are not easily available in India but can be ordered online from other countries and can cost between 10000 to 60000 rupees [23, 24,25].

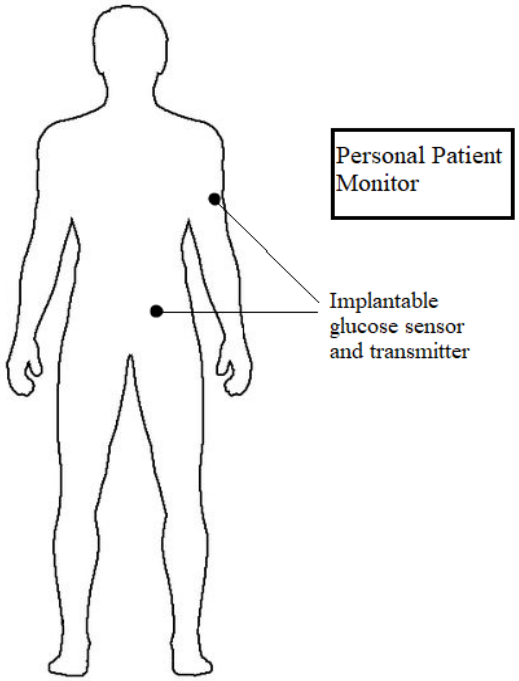

Fig. 5: placement of glucose sensors in a continuous glucose monitoring system

3.11 Pulse Oximeter

It is a sensor used to check the oxygenation level of the blood, it works by shining a light on the blood vessels and analyzing how much of the light is absorbed and how much is reflected. The device is most commonly placed on a finger, a toe or on the earlobe, as shown in fig6. The starting price of the sensors is 800 rupees and upwards depending on the variant. It uses around 20-60 mW of energy [26].

3.12 Pacemakers

A Pacemaker is a small device implanted into the chest of the patient in order to make his heart beat regular. The insertion of the pacemaker requires a surgical procedure. Pacemakers are used when the heartbeat is irregular or slow and are sometimes accompanied by other sensors to detect body activity and breathing rate to increase heartbeat during exercise. The pacemaker can function for

6-8 years and needs a replacement surgery once the battery runs out. This can be a risky procedure as there could be bleeding, an allergic reaction or damage to blood vessels. The cost ranges from 45000 to 150000 rupees [27].

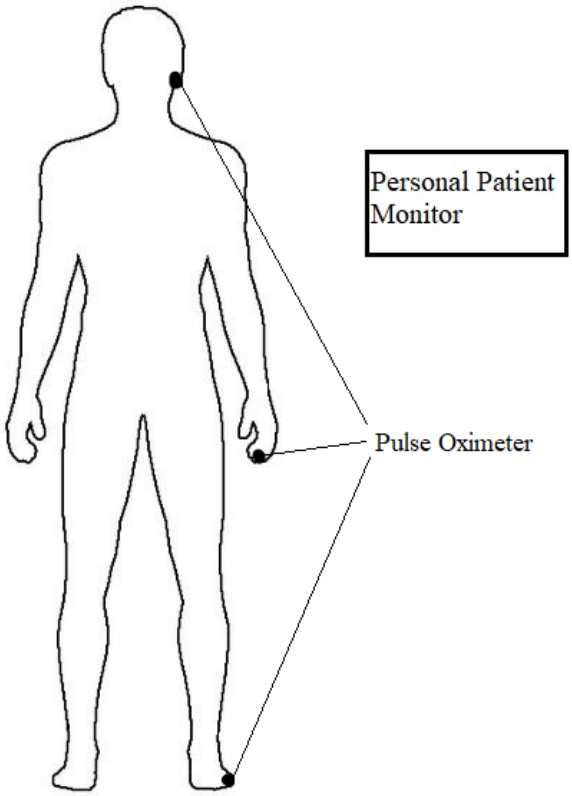

Fig. 6: Placement of pulse oximeter sensor

4. Conclusion

Introduction of Ambient Backscatter technology into the architecture of WBANs would make a huge difference. WBANs improved the mobility of the patients, but the battery life of these sensors was short and soon would need replacement. This becomes a problem with sensors that must be implanted into the body. With Ambient Backscatter technology making the sensor devices battery-less, it extends the usage period and will solve the battery crunch issues that sensor devices currently face. Thus decreasing/eliminating replacement of sensor nodes. Elimination of the RF transmitter makes the sensor devices smaller in size, lighter in weight and less expensive to manufacture. All the required components are easily available, and no special component is needed to achieve this.[1]-[4]

Improved response time to patient needs leads to better care. By detecting anomalies in the continuously generated data sent from the WBANs at an early stage, we increase the chances of the patient's survival/recovery. With different methods using different types of sensors to collect these vitals, for instance – the heart function can be monitored via the electrical signals as well as the sound it produces, we can trust that greater accuracy will be achieved in the near future. This also ensures decisions are made on the best information possible as there are no breaks in the data being generated and this data can also be stored/recorded to view trends, progress and for future analysis. Improvement in the quality of life is possible as the patient is free to move around and lead a normal life, and lesser hospitalization/hospital visits as the patient can be remotely monitored. This reduces the chances of contracting an infectious disease or infecting someone else (good for social distancing measures). It is also very useful to patients who are stationed at remote locations and don't have easy access to a hospital or clinic and to the people with disabilities. [10, 12]

Fitness and health monitoring are becoming more and more common as people are starting to realize the ill effects this sedentary lifestyle has on our health. These devices are no more used only by athletes and sportspersons, but also by the general population. Making devices smaller in size with each release seems to be driving the computer and semiconductor industry forward. The affordability of sensors is getting better as the technology evolves, hence making the market for fitness trackers bigger and promoting research and development in this field. Ambient Backscatter technology can promote this cause even more since the cost and size of sensors will be further reduced. [11, 30]

WBANs have improved the domain of remote patient monitoring and have opened up new possibilities in the health care sector promoting Telemedicine practices. The advancements are so significant that no one would have thought these things were possible a few decades ago. Although the advancements are already significant, it can be made better with the introduction of Ambient Backscatter technology in the sensor devices. Sensors are small, make use of less power and thus incorporate only a small battery in them. Ambient backscatter technology is capable of generating only small amounts of electricity and is perfect for sensors devices. Thus, improving an already useful system and fast-tracking the journey from illness to wellness.

References

[1] D. Darsena, G. Gelli and F. Verde, "Cloud-Aided Cognitive Ambient Backscatter Wireless Sensor Networks," in *IEEE Access*, vol. 7, pp. 57399-57414, 2019.

[2] Z. Ma *et al*., "Time- and Power-Splitting Strategies for Ambient Backscatter System," in *IEEE Access*, vol. 7, pp. 40068-40077, 2019.

[3] Y. Zhang, B. Li, F. Gao and Z. Han, "A Robust Design for Ultra Reliable Ambient Backscatter Communication Systems," in *IEEE Internet of Things Journal*, vol. 6, no. 5, pp. 8989-8999, Oct. 2019.

[4] C. Yang, J. Gummeson and A. Sample, "Riding the airways: Ultra-wideband ambient backscatter via commercial broadcast systems," IEEE INFOCOM 2017 - IEEE Conference on Computer Communications, Atlanta, GA, 2017, pp. 1-9.

[5] V. V. Pleskachev, "Wearable wireless ECG sensor," 2017 Progress In Electromagnetics Research Symposium - Spring (PIERS), St. Petersburg, 2017, pp. 1727-1732.

[6] M. U. H. Al Rasyid, D. Prasetyo, I. U. Nadhori and A. H. Alasiry, "Mobile monitoring of muscular strain sensor based on Wireless Body Area Network," 2015 International Electronics Symposium (IES), Surabaya, 2015, pp. 284-287.

[7] M. U. H. Al Rasyid, B. Lee and A. Sudarsono, "Wireless body area network for monitoring body temperature, heart beat and oxygen in blood," 2015 International Seminar on Intelligent Technology and Its Applications (ISITIA), Surabaya, 2015, pp. 95-98.

[8] Z. Mat, T. Zeng, G. Wang and F. Gao, "Signal detection for ambient backscatter system with multiple receiving antennas," 2015 IEEE 14th Canadian Workshop on Information Theory (CWIT), St. John's, NL, 2015, pp. 50-53.

[9] D. L. T. Wong and Y. Lian, "A wearable wireless ECG sensor with real-time QRS detection for continuous cardiac monitoring," 2012 IEEE Biomedical Circuits and Systems Conference (BioCAS), Hsinchu, 2012, pp. 112-115.

[10] S. Mandal, L. Turicchia and R. Sarpeshkar, "A Battery-Free Tag for Wireless Monitoring of Heart Sounds," *2009 Sixth International Workshop on Wearable and Implantable Body Sensor Networks*, Berkeley, CA, 2009, pp. 201-206.

[11] Z. Wu, D. Xiao, X. Peng, H. Xu and X. Zhuang, "Human Body Network: Network in the Future?", *2008 IEEE International Symposium on Knowledge Acquisition and Modeling Workshop*, Wuhan, 2008, pp. 578-581.

[12] A. Jamal, S. Hussain, A. Zafar and A. Z. Malik, "Role of Telemedicine during disaster: A Case Study," 2007 9th International Conference on e-Health Networking, Application and Services, Taipei, 2007, pp. 261-263.

[13] "Accelerometers: What they are and how they work", https://www.livescience.com/40102-accelerometers.html

[14] "Gyroscope Sensor Working and Its Applications", https://www.elprocus.com/gyroscope-sensor/

[15] "Temperature Sensors", https://www.electronics-tutorials.ws/io/io_3.html

[16] "Blood Pressure Sensor Working and it's Applications", https://www.elprocus.com/blood-pressure-sensor-working-applications/

[17] "The Introductory Guide to EEG (Electroencephalography)", https://www.emotiv.com/eeg-guide/

[18] "Element 14: MEMS Accelerometers", https://in.element14.com/c/semiconductors-ics/ic-sensors/mems-accelerometers

[19] "Mouser Electronics: Gyroscopes", https://www.mouser.in/Sensors/Motion-Position-Sensors/Gyroscopes/_/N-axg81

[20] "Robomart.com: Temperature Sensors", https://www.robomart.com/buy-temperature-sensors-module-online-in-india

[21] "What's inside a fitness tracker?", https://gadgetsandwearables.com/2019/10/01/whats-inside-fitness-tracker/

[22] "Robocraze: HRV Heart Rate ECG chip sensor kit", https://www.robocraze.com/hrv-heart-rate-bmd101-ecg-chip-sensor-kit

[23] "Medtronic: Continuous Glucose Monitoring", https://www.medtronicdiabetes.com/treatments/continuous-glucose-monitoring

[24] "National Institute of Diabetes and Digestive and Kidney Diseases: Continuous Glucose Monitoring", https://www.niddk.nih.gov/health-information/diabetes/overview/managing-diabetes/continuous-glucose-monitoring

[25] "Dexcom Continuous Glucose Monitoring", https://www.dexcom.com/g6-cgm-system

[26] "how equipment works .com: How pulse oximeters work explained simply", https://www.howequipmentworks.com/pulse_oximeter/

[27] "Mayo Clinic: Pacemaker", https://www.mayoclinic.org/tests-procedures/pacemaker/about/pac-20384689

[28] "bio-beat Medical Smart Monitoring Real-time, Wireless, Continuous", http://www.bio-beat.com/

[29] "Remote Monitoring Solution From VitalConnect Reduces Readmissions", https://insights.samsung.com/2019/01/31/remote-monitoring-solution-from-vitalconnect-reduces-readmissions/

[30] "What is quantified self?", https://www.livescience.com/39185-quantified-self-movement.html

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