Advancements in Smart Biomedical Wearable with Technical Challenges

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Abstract

The emerging wireless body area network (WBAN) has profound impacts in our daily life, such as pervasive medical supervision and outdoor exercises, and the large scale application of wireless body area network can effectively reduce higher cost burden owing to the aging society and long term healthcare for the chronic illness. It can also enhance the quality of life for elderly people and chronic patients and decrease the harm of the sudden diseases. Health monitoring, telemedicine, military, interactive entertainment and portable audio/video systems are some of the applications where WBANs can be used. The miniaturized sensors together with advance micro-electro-mechanical systems (MEMS) technology create a WBAN that continuously monitors the health condition of a patient. This paper presents a comprehensive discussion on the applications of WBANs in smart healthcare systems. It highlights a number of projects that enable WBANs to provide unobtrusive long-term healthcare monitoring with real-time updates to the health center, in addition the paper presents recent advances in biomedical wearable along with technical challenges.

Keywords – *Wireless, Wearable, Healthcare*

I. INTRODUCTION

BANs are commonly regarded as an enabling technology for a variety of applications, including health and fitness monitoring, emergency response and device control. Recent breakthroughs in solid-state electronics afford for the creation of low-power, low-profile devices that can be modularly interconnected in order to create so-called sensor nodes comprised of one or more sensor devices, a microcontroller unit (MCU), and a radio transceiver that eliminates the need for wires to communicate with the coordinator node in order to transfer the collected data. These newer devices are single chip hardware solutions that provide a microcontroller and a radio transceiver in a single package requiring only a few external components.

It has given their huge potential to support distinct applications; BAN technology is at the beginning of what can be expected to develop into multi-million dollar industries over the next few years. In their most basic form, sensor devices operate by preloading MCUs with program multi-million dollar industries over the next few years. In their most basic form, sensor devices code those access low-level hardware interfaces, which in turn obtain data from the actual sensor devices. Programs contain the necessary instructions for sensor devices to collect one or more readings in a particular time period. Raw sensor data can be subsequently processed in order to convert them to meaningful information that can be interpreted after transmission by the radio chip to an external device or system for further analysis. These sensor nodes are meant to be either worn around or implanted in the human body. Moreover, two or more sensor devices in the vicinity of each other can establish wireless links in order to coordinate their joint operations, thus creating a networked system. Therefore, the existing literature often refers to BANs as wireless BAN (WBAN) or wireless body area sensor network (WBASN).

II. MONITORING AND SENSING

In this section we begin with a review of some of the advanced wireless sensor technology that has evolved recently for detecting various body parameters and other applications.

A. Sproutling baby monitor

Fig. 1: Sproutling baby monitor

Sproutling baby monitor has given new twists in the monitoring of baby. It has included cameras and smartphone control some even have night vision, baby monitors always served more as a security blanket than a security system. Sproutling’s baby monitor system starts with a small rubber-coated sensor that attaches via a soft, hypoallergenic, machine washable strap to the leg of the child (age group 0-2) and monitors temperature, heart rate and motion. It has the charging dish, which serves as a secondary sensor array when the device is in use. It evaluates room temperature and ambient noise barking dogs and lawn mowers. The third piece of the system is the app. There are no video feeds, or even an audio channel. Instead, there's a primary-colored interface showing an iconic representation of your child's state: cranky or happy, sleeping or awake. A sweeping loop indicates not just how long your child has been asleep, but how long he or she ought to sleep, based on age, history and current conditions. The Sproutling dock can wirelessly charge the wearable sensor, and also collect environmental information like room temperature and ambient sound.

B. QardioCore for cardio health

Fig. 2: QardioCore for cardio health

Patients suffering from cardiac diseases such as heart attacks and strokes now have a new way to relay information to their doctors. The QardioCore is a device that will help to monitor us and can then transmit the information directly to our doctor. We can wear this device all day and allow our doctor to take ECG telemetry while we do your normal activities. This can help him diagnose issues quickly and more definitively. Now monitoring devices are available that we wear for two or three days while we do normal activities and take the results back to our doctor who tries to analyze what we did in the past 48 to 72 hours. He can still see where there may be heart problems during strenuous activities but it is hours if not days after the fact. With the Qardio device he'll know immediately, that immediate knowledge could be enough to save a person's life.

We don't have to prep skin to use it. Older devices require leads attached with adhesive and men would have to shave their chests. This device attaches to your chest. Once in place the device switches itself on and begins the wirelessly transmitting data. The electrodes usually found on the patches in regular ECG monitors are directly embedded into QardioCore sensor, making it much more user friendly, while still maintaining the capacity of a medical grade electrocardiogram.

C. Ampstrip

Fig. 3: The Ampstrip

The Ampstrip is 3.5 inches long, 1 inch wide and is less than one quarter of an inch thick including the adhesive. It weighs less than 0.4 ounces. It captures continuous heart rate plus other important metrics like rest and recovery. It stores your data until the next time you're near your device. Electrical is better than optical. It won't lose the signal during an intense workout, it small and discrete, you won't even know it's there. It uses a single lead ECG sensor to capture heart rate with precision. We use a 3-axis MEM's accelerometer to detect motion in all planes which is converted by our proprietary algorithms into specific activities and effort levels. We also include skin proximity Thermistors to detect skin temperature. It contains one level of replaceable adhesive for use with AmpStrip, the Competitor grade. Competitor grade is designed to stay on under the most rigorous conditions, including pool and ocean workouts and strenuous whole body efforts for 3 or more days. It uses patented techniques in conjunction with Bluetooth 4.0 (BLE) to achieve significantly reduced energy consumption and maximize data capture and battery life. The AmpStrip uses a 20 mA wireless rechargeable battery. The sensors, processing unit and battery are housed in a fully sealed medical grade silicone module for durability and protection. This module is waterproof and operates on temperatures from 40-110^0 F. Under constant daily use in normal conditions the battery will only need to be recharged every 7 days or so. Integrated memory allows for up to 24 hours of data collection between background syncing, giving users untethered freedom to train without worrying about their gear. It uses a 32 bit ARM MO processing unit to manage the continuous heart rate, activity, body position, etc. monitoring.

D. Smart glasses

Fig. 4: Smart Glasses to detect fatigue

The Jins Meme glasses tracks eye movement to identify when fatigue levels are on the rise, offering up useful data to better manage our work loads. An app for Google Glass called DriveSafe, designed to monitor the drowsiness of the wearer and keep them from falling asleep at the wheel. The system relies on three Electrooculography (EOG) sensors located in the base of the frame, the nose pads and above the nose. EOG measures eye movement and blinking by tracking retina position in relation to these sensors, while six-axis accelerometers built into the ends of the arms are intended to monitor the body's axis and walking behavior. Data collected by the sensors is presented through an iOS and Android smartphone app, which offers insights into things like the wearer's fatigue levels, when they should take a breather from their work, how many steps they've taken, how many calories they have burned and even feedback on their posture. There is also a series of more ambitious applications in the pipeline, including games where eyes would act as the controller, functions to measure interest levels, focus-training exercises and potentially tools to tackle neurodegenerative diseases.

E. Smart Ring

Fig. 5: Smart ring

A pulse oximeter measures the oxygen saturation levels (SpO2) in an individual's blood as well as the changes in blood volume in the skin that coincide with the cardiac cycle. Typically, a pulse oximeter is attached to a finger or an earlobe, and it consists of red and infra-red light-emitting diodes (LEDs) and a photodetector. The photodetector measures the amount of red and infra-red light that is transmitted through or reflected by the body part, which is partially dependent on the amount of light absorbed by the blood that perfuses the body part. The relative absorption of red and infra-red light by the blood is related to the ratio oxygenated hemoglobin to deoxygenated hemoglobin, and this serves as the basis of the SpO_2 measurement. The overall amount of light absorption varies as the pulsatile volume of blood within the body part changes with time.

F. Wearable that work with car

Fig. 6: Wearable that work with car

Wearable that cooperate with automobiles are also been developed. Mercedes has an app for Pebbles smart watch, which let the user quickly report road accident, warned of road herds, etc. BMW showcased an app for Samsung's Galaxy Gear for drivers to monitor BMW i3 electric car's vital parameters and control its features from a distance. Nissan's demonstrations of its Nismo smartwatch with the company's 331 hp sports car 3702 shows the possibility of measuring not just car metrics like speed and fuel consumption, but also monitor car racer's heart-rates to detect fatigue.

G. Quell physiopherapist

Fig. 7: Quell physiopherapist

Any time we experience pain in our knee, elbow, back or wherever, we go to the doctor, who prescribes medicines, exercises and physiotherapy. All therapies seem to be very effective when we undergo these, but in many cases, bang, the pain is back in an hour. Quell claims to be the first ever wearable pain-relief solutions, is a discreet device equipped with a special electrode and a comfortable band that lets you wear the device on your calf muscles, 24x7. OptiTherapy technology stimulates nerves on your upper calf, which, in turn, carry sensory signals to your brain to trigger a pain-relief response in your central nervous system. This blocks pain signals throughout our body, relieving pain due to any physiological condition, be it diabetes, bone degeneration, sciatica or fibromyalgia. The stimulation is optimized to your body condition, and the activity you are performing, detected using an accelerometer. For example, when we are asleep, the system shifts to night therapy, ensuring deep and comfortable rest. The device connects with an iOS app to monitor our therapy and quality of sleep. The power efficient device also offers around 40 hours of relief on a single charge.

H. Pet care with FitBark

Fig. 8: Better pet care with FitBark

FitBark is much better wearable device that helps pet's health. A small device that can be clipped to your dog's collar, FitBark monitors and tracks the activity and rest patterns of our dog. The eight gram device is equipped with an accelerometer, Bluetooth technology to sync with the mobile app and a battery that, apparently, needs to be charged only once in two weeks. Based on the accelerometer data, the app calculates your dog's activity, play and sleep time, and compares it with the healthy average of that breed. Like most human fitness trackers, the app lets you look at information in various views to accumulate, compare and monitor the health of your pup.

I. Smart Necklace

Fig. 9: Smart Necklace

A new smart necklace recently developed track's people's food and drink consumption to prevent overeating. The WearSens, a close-fitting metal necklace, is able to determine what a person is putting in their mouth by measuring the vibration that occurs as the food is swallowed and digested. As a substance moves down the throat, it creates tremors that can be felt on the skin around the neck. The necklace's piezoelectric sensors are sensitive to mechanical disturbances and are able to record these vibrations. The device is able to distinguish between solid and liquid food 90 percent of the time and it could distinguish between hard and soft foods roughly 75 percent of the time.

J. Smart LifeShirt

LifeShirt is a comfortable and completely non-invasive smart garment that gathers data during a patient's daily routine, providing the most complete remote picture of a patient's health status. It enables healthcare professionals and researchers to accurately monitor more than 30 vital life-sign functions in the real-world settings where patients live and work. LifeShirt collects patient data using integrated sensors including respiratory bands and an ECG It also tracks and records posture and physical activity.

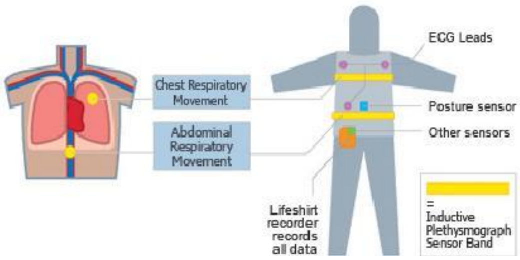

Fig. 10: Smart LifeShirt

III. TECHNICAL CHALLENGES

The widespread adoption of technology employing WBANs still faces many technical hurdles, among which battery drain is a critical one. This problem requires attention from both the hardware and software fronts. On the hardware side, recent advances in solid-state electronics enable the production of MCUs and radio chips that consume electric currents in the Nano-Ampere range when operated in low-power modes. However, when in active mode of operation, the power consumed by a radio chips depends significantly on the amount of data transmissions, radiated power and duty cycle. In the latter case, radio chips that transmit/receive at low data rates would expect to see an increased duty cycle in order to send/receive relatively large amounts of sensor data. This is where computer scientists and software engineers can help by creating efficient sensor data processing algorithms that reduce the amount of radio transmissions and save battery power. However, excessive data processing routines effectively shifts power consumption and active duty cycles from the radio chip to the MCUs, though the latter regularly consumes less power compared to the former. This circumstance normally warrants trade-off analysis for the particular application being developed.

A. Environmental Challenges

WBANs experience high path loss due to body absorption that must be minimized through heterogeneous and multi-hop links with different types of sensors at various locations. Additionally, change in operational conditions may lead to error-prone and incomplete sensor data relative to inherent sensor limitation, human postures and motions, sensor breakdown and interference. As health care facilities and human subjects have specific regulations, the design of implants and wearable devices becomes crucial.

B. Physical Layer Challenges

PHY layer protocols should be designed to minimize power consumption without compromising reliability. PHY protocols should be convenient for interference-agile places where high-power devices use the unlicensed bands. Advancements in low power RF technology is expected to significantly lower the peak power consumption, which leads to the production of small, disposable and low cost patches. Technically, WBANs are required to be scalable and have peak power consumption between 0.001-0.1mW in stand-by mode and up to 30mW in fully active mode.

C. MAC Layer Challenges

The MAC protocol should be robust enough to support multiple WBANs in parallel applications. Thus, reliability is of major importance in such networks. In this regard, the IEEE 802.15.6 standard has allowed the deployment of dynamic channel hopping, which assists the network to minimize interference from other narrowband transmitters. In addition, MAC protocols must support the energy efficiency requirement of WBAN applications, prolong sensor lifetime, allow flexible duty cycling and save energy by periodically switching the radio on/off. Channel polling must be used to check if the nodes are awake to transmit/receive instead of idle listening. Nodes with low duty cycle should not receive frequent control packets and synchronization if they do not intend to send or receive data.

D. Security Challenges

Due to limitation of resources in terms of energy, memory, processing power and lack of user interface existing security mechanisms proposed for other communication networks are not applicable to WBANs and more resource-efficient and lightweight security protocols need to be developed. As an example, an adversary could be capable of inducing heart failure by the detection and execution of vulnerabilities in an Implantable Cardioverter Defibrillator (ICD). Moreover, numerous non-technical factors are trivial to mass marketing in WBANs such as acceptance, comfort, user friendliness, regulatory, affordability, regulatory, ethical and legal issues

E. Transport (QoS) Challenges

WBAN may have different frequency, data rate and power requirements. Hence, the chosen wireless technology must be capable of handling a mixture of these requirements. In terms of QoS, episodic data, real time wave form data, periodic parametric data and emergency alarms need to be. QoS features such as bandwidth, reliability, delay, etc., require comprehensive study. The desired QoS could also affect energy consumption, which is one of the prominent requirements in WBANs. For instance, to achieve a lower packet loss, the transmit power should be increased, which also increases the relative power consumption. One other pitfall that most WBAN researchers need to be aware of is that the characterization of an on-body link as LOS or NLOS is not practical or meaningful as the signal states vary as much from NLOS to LOS because of dynamics, changes in posture and body movements. Whilst the rate of movement needs to be captured to statistically characterize the path loss of the link. Another major pitfall is the danger of relying on a one hop star topology as such a network cannot be sufficiently reliable for WBAN communications specifically in health care applications that require the use of relays and cooperative communication for reliable communication.

IV. CONCLUSION AND FUTURE WORK

This paper aims to provide an overview of recent advancements in smart biomedical wearable with technical challenges. Now a day's most of the wearable biosensors are used in daily life such as Sproutling baby monitor, QardioCore for cardio health, The Ampstrip, Glasses detect fatigue, Smart ring, Wearable that work with your car, Quell physiopherapist, Better pet care with FitBark, Smart Necklace, Smart LifeShirt. For the consideration of individual, many applications and techniques of these sensors are introduced.

These systems may include anything from monitoring the elderly or patients undergoing surgical operations to advanced sensor supervision in the case of infant respiratory disorders or soldiers on the battlefield. Pharmaceutical companies are now undergoing a sort of revolution of their practice. Wearable systems feature a broad and heterogeneous range of devices, WSN standards, applications, and involve the efforts or numerable researchers, developers and users. Due to its interdisciplinary nature, a number of applications related to health care integrate biomedical engineering and medical informatics. Other knowledge in the fields of medicine, social sciences, psychology, economics, ethics, and law must be taken into account and be integrated into the development and deployment of wearable healthcare systems. We are pointing some challenges in this area. So, we can conclude that from sports and fitness to clinical diagnostics, wearable sensors have a great impact on the future care.

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