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Wearable Biosensors in terms of Energy Consumption, Placement and Communication Level: A Survey

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Abstract: This document gives formatting instructions for authors preparing manuscripts for publication in the International Journals/Conferences with ER Publications on a wide range of subject areas given in "Topics Covered". The document contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided that explains how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of acknowledgments, references, and authors' biographies. The abstract is limited to 150 words and cannot contain equations, figures, tables, or references. It should concisely state what was done, how it was done, principal results, and their significance.

Keywords: Wearable Biosensors, Healthcare.

Introduction

Previous work done in wireless technologies and currently available wearable bio-sensors for healthcare applications are reviewed. Wearable bio-sensor systems for health care monitoring are an emerging trend and have gained a lot of attention in scientific community during last years. Wearable biosensor systems will potentially transform the future of healthcare and are expected to enable personal health management and ubiquitous monitoring of patient health condition and better treatment in various medical conditions.

These systems mostly comprises of various types of small physiological sensors, transmission modules and processing capabilities. Thus are providing a low cost wearable unobtrusive solutions for continuous all day and any place health, mental and activity status monitoring.

This paper presents a comprehensive review on research and development done in wearable bio-sensors for healthcare so far. A variety of system implementation regarding bio-sensor devices, communication architecture, standards and designs, placement of wearable biosensors on human body, power consumption of Bio-sensors in different scenarios and communication level of wearable bio-sensors are discussed by keeping different aspects in view.

Service functionality is described in section 2.In section 3 many types of wearable biosensors are discussed with their flexible placement on the human body. Section 4 introduces the different methods of power consumption for the wearable biosensor devices and Section 5 describes the communication levels mostly use in the communication of wearable sensors with destined places (caregivers). Section 6 draw conclusion.

The goal of this writing is not to criticize the work already done but to serve as a reference for the new research and development in the field of wearable biosensors for healthcare.

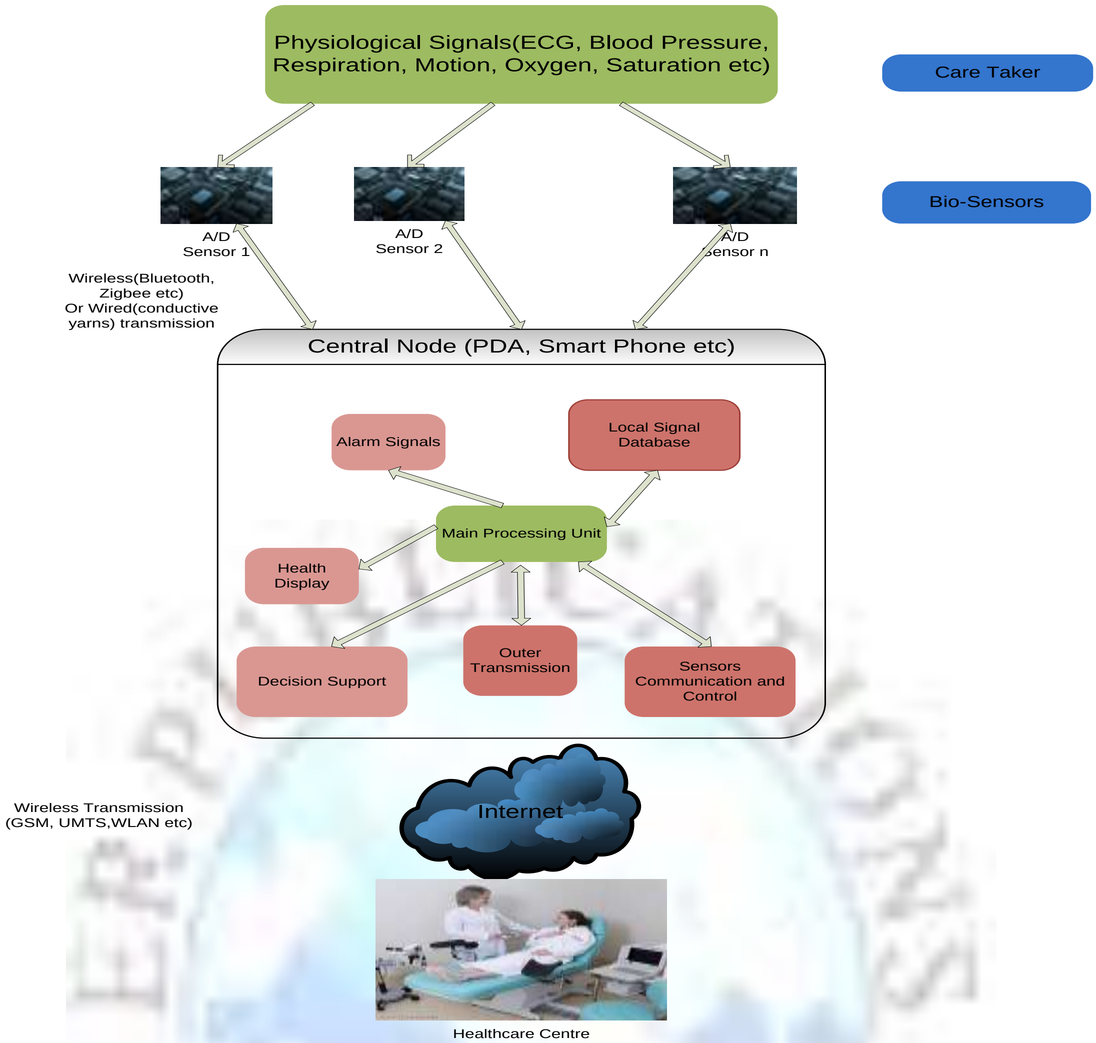

Figure 1. Basic communication architecture

Related work and motivation

In [1], author has described the wireless network which provides more functions comparing existing wireless healthcare equipment. This terminal also works as a nurse call terminal that can be used everywhere, every time. Recently various kinds of wearable biosensors become available for continuous healthcare management purposes, however, these equipments are

Purposes and purposes a wireless network featuring nurse call, positioning and biosensor functions. Current wearable sensors been reviewed, further more improvement in accuracy and stability is investigated for wrist watch temperature and pulse sensor.

In WSN for Health Application [2], author says that the researchers in computer, networking and medical fields are working together in order to make the broad vision of smart healthcare possible. The importance of integrating large scale wireless telecommunication technologies such as3G, Wi-Fi and WiMAX, with telemedicine has already been addressed by some researchers. Further improvements will be achieved by the co-existence of small scale personal area technologies like radio frequency identification, Bluetooth, Zigbee and wireless sensor networks, together with large scale wireless networks to provide context awareness applications.

The author has focused on the wearable healthcare of patient in long-term interval of time in [3], as the main goal is to continuously monitor the person's health during normal daily life, since chronically diseases require long-term continuous healthcare convenience of usage becomes of primarily interest in realizing a wearable healthcare system. Conventionally clinical or normal healthcare is based on wired technology which is better than the wireless technology but in this case a person's mobility gets at zero level, it provides wearer zero level of freedom of movement, hence wearable wireless technology takes over, also that can adhere to human skin so in this case fabric patch sensors are used with dry electrodes.

In Energy Harvesting Implantable Bio-sensors [4] author mainly focused on the power consumption of the wearable biosensors at time when they are in use with wearer, according to author in order for any wireless biosensor device to be convenient for the wearer it should not require the user intervention. power supply for such devices should be maintenance free and supply power for the unlimited time period, so no such device have still been made, so researchers searched out some other way to get energy for the wearable biosensor device to keep it as long as unlimited, in this case a new concept arrived of to harvest energy from the human body itself, as human body generates some of energy that can be used to power up tiny biosensors, this energy proposed in the form of inertial kinetic energy and thermoelectric energy.

Research challenges in bio medical sensor applications and experiments on solutions for challenges like low power systems, high performance, wireless communication availability, for this the author gave an approach in [5] for the power management of devices via the extended power state machine and has given the wireless communication vie general packet radio service of the standard Global system for mobile communication, the wearable biosensor is connected to cellular network directly which sends the information to the caregiver**.**

Placement of wearable biosensors on human body

In continuous monitoring of chronic diseases wearable health care is one of the promising applications. Because a patient has to continuous monitor the wearable biosensors device should be capable of long-term usage which also do not limit wearers mobility and adhere to human skin, in this regard different types of biosensors according to their placement on human body are discussed as:

A. Band-aid fabric patch sensor

This Band-aid fabric patch sensor is made up of fabricated textiles using Planner-Fashionable circuit board which is disposable after usage. It is placed on the chest of wearer as its base station is attached on the vest and its biosensors are placed underneath vest according to the base station position. This sensor records Electro-Cardio gram data from its positions specifically while great care has been taken in the use of electrodes, as wet electrodes irritates the human skin in long term monitoring so in band-aid fabric patch sensors dry electrodes have been used.

B. Smart Poultice type fabric patch sensor

This smart poultice type sensor is also placed on the chest but with some extended features as other fabric patch sensors are only to record for Electro-Cardio gram data, but this poultice type sensor proposed that more sufficient hemodynamic parameters can be extracted by measuring Electro-Cardio gram signals together with bio-impedance in the thorax which plays a major part in therapy of heart diseases, so its chest placement extended to neck. But in the use of electrodes it has the same scenario as it also do not use wet electrodes on biosensors as it irritates the human skin in long term monitoring so in poultice type fabric patch sensors dry electrodes are used.

C. Life Minder biosensor

This type of sensor is placed on the wrist of the wearer as it detects 3D acceleration, pulse, temperature and galvanic skin reflexes, Life Minder gives healthcare services on the bases of detected data or it is used for real time applications.

D. Pulse Oxi-Meter

This type of sensor is placed on the fingers of wearer as it is ring type biosensor used for the oxygen density in blood and pulse every 60 seconds.

E. Ear Type Temperature Logger

It is placed in the inner ear for the detection of infrared radiations from the eardrum. Temperature is also measured.

F. Glucose Monitoring system

It is a free style navigator attached on the back of arm or abdomen which detects glucose density continuously.

G. Energy harvesting sensors

These type of sensors are placed on the knee as a knee brace or a back pack, used to produce energy from the human body itself.

H. Hip-Guard sensor

It is used for a posture analysis application. It's a posture detection system intended for the recovery period after hip replacement operation, placed on waist, thighs, shins and feet but it is integrated into the garment that helps unobtrusiveness and comfort of the whole system.

I. Special Goggles

As by name this type of sensor is placed at the place of glasses (eyes).it has rotator vertigo, a wearer having reading or writing deficits used for Electro-Oculography which is also similar to Electro-Cardiogram.

J. eWatch

It is a wrist wear bio-sensor which senses light, motion, audio, temperature and it gives audio, visual and tactile notifications.

K. Screen printed Electro-chemical sensors

This type of sensors is placed on the human body as under water garments for aquatic environments. It is made up of synthetic rubber neoprene and provides visual indications.

L. Impact Sensors

These type of sensors are of foot wear usage for athletic support, removes stress and strains on limbs specially used for rugby players, high jumpers and runners etc.

M. Squid Sensors

These sensors are placed on the chest at human body, it target tumors specially used for the cure of breast cancer.
These bio sensor types are shown in fig 1 hierarchy according to the family/type they belongs as

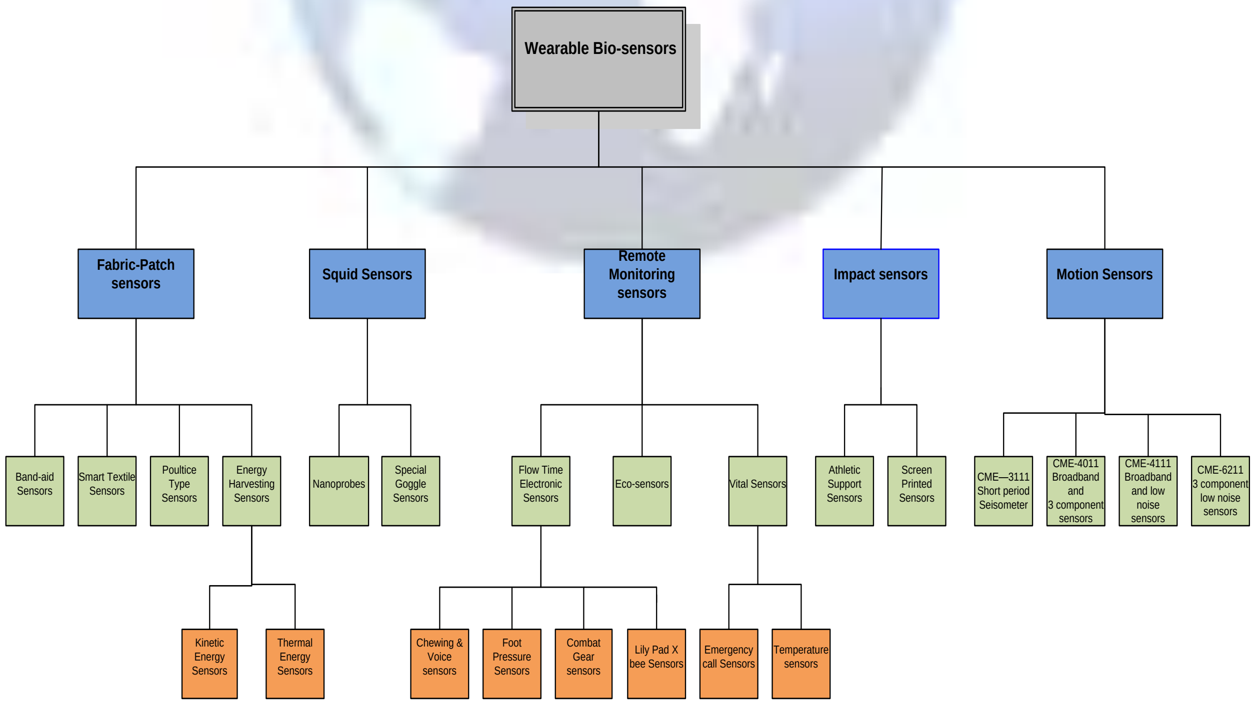

Figure 2. Types of Bio-sensors

Power Consumption of Bio-sensors in different Scenarios

A wearable device has power restrictions ,since there are no wires to connect to power supply, The usual approach in this case is to supply power to wearable bio-sensors with batteries, renewable power sources based on solar energy or mechanical vibration which are under study, other power resources possibilities includes transference of energy via radio-frequency or infra-red signals. But in the case of wearable bio-sensors approach is different because it is not possible to change batteries every time, also depends on the place of the human body part at which the sensor is placed and shape, size, weight and material of the bio-sensor is also restricted. In order to compare power consumption in bio-sensors and analysis is done in different cases in different types of sensors as:

A. Fabricated patch sensors

As these are made up of fabric electrodes, for example; band-aid fabric patch sensor comprises an instrumentation amplifier, an analog to digital converter, an adaptive threshold rectifier and an amplitude shift keying modulator. This sensor is tuned for Electro-Cardio gram signal. When attached, the sensor captures Electro-Cardio gram by a pair of fabric electrodes. After analog to digital conversion, the packet modulate incoming signal by load modulation. Under such power limited environment, average power consumption is as low as 12µW. Some other types of Fabricated patch sensors with enhanced features consumes power accordingly as poultice type bio-sensors gives ECG record as well as bio-impedance in the thorax, also consumes only few mW-level power from the battery.

B. For ECG signal Transmission in healthcare systems

When any bio-sensor transmitting ECG signals to a remote station via wireless channel the average power consumption is 0.450W for analog and 0.384 W for the digital signal transmission. The power dissipation has made lower by reducing the activities (I/O operations) of devices when they are not in the active states.

C. Energy Harvesting for Human and implantable Bio-sensors

As discussed that wearable devices has power restrictions, so in order for wearable bio-sensor device to be truly convenient, it should not require user intervention, because power with batteries have to replace frequently which is not convenient to wearer as well as caregiver. Energy harvesting from the human body motion for powering biosensor is often significantly more difficult than extracting energy in a vibration and temperature rich industrial environment.

To overcome the issue finally energy harvesting from the human own body is proposed, it can be produced in two types of energy, Inertial Kinetic energy, devices which generates kinetic energy from human body while in motion are taken into account and Thermoelectric energy, which can be produced using thermo electric devices in bio-sensors for human healthcare applications. These two methods of producing energy from human body is very innovative in the field of wearable bio-sensors and are by using in different types of bio-sensors.

Communication level of Wearable Bio-sensors

Many available wireless technologies and wearable bio-sensors are reviewed, in all that, some of them are point-to-point and some of them are having number of wireless connections between their healthcare systems. In both of the cases there are some limitations; these limitations can be of network or bio-sensor systems as well.

A. License Free Communication:

In order to design a flexible network to overcome the limitations some already proposed wireless standards (802.15.2 Bluetooth) and (802.15.4 Zigbee) are used to design another new short range wireless network for wearable biosensors healthcare system. In this system, infrastructure of Wireless Fidelity is used but processing of network is solely on the wireless standards (802.15.2 Bluetooth) and (802.15.4 Zigbee).

Different Access points and coordinators are used to complete the network infrastructure and a new techniques for short range wireless network and wearable biosensors for healthcare applications are available.

B. GSM/GPRS:

Biosensors can work in two types of environments, wired or wireless. As there are always tradeoffs in the fields of performances and evaluations, like in wired there must be having a very high signal quality and bio-sensors performance and due to there is no power issue in wired bio-sensors system it also gets high from the wireless bio-sensors system. In wireless bio-sensor system there is low performance of bio-sensors as power consumption issue and signal quality issue matters a lot. But the tradeoff between these two technologies is this that there is not any mobility in the wired network and there is high mobility in wireless network, this feature of wireless bio-sensor networks take it higher as the need of hour is to get mobility as it is very basic need of care givers as well as caretakers. This mobility in this case is achieved by directing wearable biosensor networks directly on the cellular network, GSM/GPRS. In table 1, these wearable biosensors are discussed along with their

- Wear ability
- Application Features
- Network support/communication media
- Bio-signals

Table 1. Communication level and application support of wearable biosensors

Name/ description	**Wear ability**	**Application Features**	**Communication/ Network support**	**Bio-signals**
BSN Earpiece	Ear-worn device	Real time App.	Zigbee	Heart Rate, Sa02
Remote Monitoring Sensor	Mask, glove,	Mobility	GPRS/GSM	Galvanic Skin response/ Heat Flux
Energy Harvesting Sensors	Human body	Ultra low power consumption	GPRS/BT	Temperature
Vital Sensor	Arm/wrist worn	Emergency Call	GSM/GPRS	Temperature, pulse
SQUID Sensor	Chest	Target Tumors/ Breast Cancer	802.15.4 BT, A	Mammography/ Nano probes
Screen Printed Electro-chemical Sensor	Under Water Garments	For Aquatic Environments	Wired/802.15.4	Respiration
Impact Sensors	Foot Wear	Stress & Strains on limbs	GPRS/GSM	Galvanic skin Response
Fabric Patch card	Chest/as vest	Dry fabric electrodes	Zigbee/Bluetooth	Electro Cardiogram/ Heart rate

Conclusion

Wearable bio-sensors and wireless technologies for health applications are currently available and are reviewed. In this paper different types of wearable bio-sensors are studied and are tied up together in the same contexts which are having the same common features. These wearable bio-sensors types and configurations are also previously discussed but what we have done we have merged all the salient aspects of these bio-sensor technologies and evaluate in the single context. Like we have tied up the energy harvesting sensors in the Fabric Patch sensors, it means that if energy harvesting sensors made work with Fabric patch sensors in a way that Fabric patch sensors works on the energy gained from the human body, whatever it is kinetic energy or thermal energy, its performance would get better. More precisely when we would use Fabric patch sensors with kinetic energy and the patient is in the walking state, it would perform better and we would use fabric patch sensors with thermal energy and patient is in running state, its performance would be better. The most important thing in all this is when we would take this whole scenario’s advantage with remote monitoring system. In this case mobility of a patient and caregiver would also be ensured. Moreover the concept of remote monitoring furbishes in the case of flow-time electronic sensors by which foot pressure sensors, combat gear sensors, lily pad X bee sensors can be also remotely monitored. Also motion sensors and impact sensors has very effective impact on human’s life using wearable bio-sensors.

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