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Healthcare Biosensors - A Paradigm Shift To Wireless Technology

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Abstract: Health is the most important part of the existence, and is in today's age the most critical, costly and time consuming area. People want to safeguard their health and take all the necessary precautions all by themselves, moving to the healthcare facilities only at dire need. A leading technology paradigm is the use of biosensors in quantifying the biological and physiological parameters and transferring the result to a GUI for health monitoring without the assistance of any healthcare personal. These biosensor enabled devices are becoming very popular in the masses as they can themselves monitor their health. Biosensors coupled with the wireless technology offer pervasive ubiquitous remote health monitoring and being extremely small enhances the users mobility with simultaneous monitoring. The work has discussed the biosensor structure and its importance in healthcare. Various breakthroughs in the biosensor innovations have been listed. A varied discussion about the integration of the wireless technology with the biosensors has been done, emphasizing the importance of real-time healthcare monitoring, and lastly a literature survey for the above-mentioned areas has been given.

Keywords: BAN, Biosensors, BSN, Implantables, IoT, Wearables, WBAN, WBSN, Wireless Healthcare.

I. INTRODUCTION

One discovery, one innovation leads to another and so forth fashioning a never-ending chain reaction of changes and innovations. The innovations that today's world is seeing can all be attributed to the innovations that were witnessed almost before an era. The Internet of Things (IoT) has realized a phenomenal transformation in almost every persons' life, may it be their internet activities or healthcare; no field has remained untouched by the IoT.

Saying of the healthcare field, an innovation is being led on by the usage of sensors in the prognosis and diagnosis of not only the patients under observation but also the healthy people, for at any time an emergency can arise. This kind of healthcare may be defined as the preventive healthcare. The healthcare facilities in today's date are becoming costlier [1] day by day and time consuming too. The waiting period for the consultation with health personnel has drastically increased not only with the increase in the population but also due to demographic conditions. People are seeking an alternative to these traditional healthcare systems and are taking the healthcare mission in their own hands. An upcoming solution is the application of sensors in healthcare- a technological medical revolution. Sensors are benefitting from technological innovations to spread very fastly in healthcare and in almost 10yrs [2], the biosensors would be ubiquitous in healthcare. The sensors are capable of sampling the physiological data, processing it and communicating it over the network [3]. JeongGil Ko et al. [12] have strongly advocated the collection of physiological data and coupling it with the sensor networking in the healthcare field for early diagnosis, emergency care, real-time monitoring and quality of life improvement.

The sensors that are particularly used in healthcare and medicines are basically of two types, the biosensors which are used in determining the target biomolecule in the biological system and the regular sensors which are able to monitor the physical parameters like temperature, pulse, movement etc. In this paper, the concentration is on biosensors. The biosensors actually use a biorecognition process coupled with an electronic signalling system. It has been exactly 54 years since the initiation of biosensors in healthcare. The first biosensor was developed by Leland C Clark in 1962 by building an enzyme electrode, which formed the basis for future biosensors. Primarily the first application of the biosensor was the glucose monitoring and so far, it has found an extensive market. In this almost half century the healthcare facilities have gone through a varied change, the innovation of biosensors, the innovation wired technology for integrating biosensors with healthcare, to quantify physiological and biological parameters and now the wireless technology for integrating biosensors with healthcare. The biosensors are not only taking a leap to wireless technology but the market is shifting from wearable biosensors to implantable biosensors.

These biosensors are capable of detecting a varied compounds like glucose, oxidases, peroxidases, nucleic acids, antibodies etc., that have encouraged researchers to develop newer sensor technologies for the current market. Coupled with the communication technology and the miniaturization of these biosensors, the measurement of patient data has become very much easier. Lucrative biosensors must be able to support a number of biorecognition elements, in add the sensor miniaturization should be viable with being easy to operate with being

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cost effective [4]. Now-a-days handheld devices are used to monitor the vitals, and the data is sent over wirelessly to the healthcare personnel or the personal devices of the patients, so that the vitals can be monitored easily. All this forms a network for healthcare that can be variously discussed further.

In Section II, an overview to the structure and working of biosensors is given, in Section III marked innovations in biosensors, in Section IV the leap of biosensors to wireless technology, in Section V a literature review of biosensors and wireless healthcare networks and in Section VI the work has been concluded.

II. OVERVIEW TO BIOSENSORS

The credit for the invention of the biosensor goes to Prof. Leland C Clark Jr. in 1962, who is also known as the father of biosensors.

A. Structure of Biosensor

A typical biosensor can be described as a sensing device that takes the input as the biochemical reactions to detect the chemical compounds (which are transmitted as electronic signals) of the particular reaction in the given biological samples. A biosensor is foremost formed by the integration of three main elements [5] (i) a bioreceptor (ii) a transducer (iii) microelectronic signal processing system.

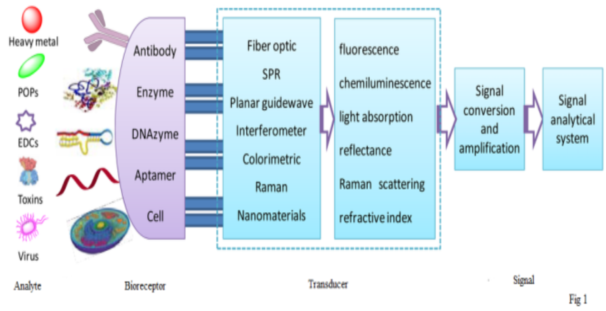

Fig. 1. Structure of Biosensor

Bioreceptor: a bioreceptor is simply the sensing element that is integrated with the immobilized biological compounds that are sensitive to a particular compound. The bioreceptor acts as a substrate for the undermining compound. A bioreceptor can be an enzyme or an antigen or DNA, etc.

Transducer: a transducer works out the simple process of conversion of the compound recognition event that occurs between the analyte and the bioreceptor in to an electronic signal.

Immobilization of Bioreceptor: the foremost requirement for the success of any biosensor is that the bioreceptor molecules have to be immobilized [6], so that the molecules are permanently near the transducer element. As without immobilization, the transducer is not able to convey the signals. The immobilization can be achieved by either the chemical entrapment or the physical entrapment.

The concise functioning is given in the below piece.

1. Analyte: can be the sample of protein or toxins or anything else, which we have to analyse to determine a particular compound like oxygen or nitrogen or glucose.
2. Sample Handling: is the process of delivering the analyte to the region where detection can be done.
3. Detection: the process of specifically distinguishing the analyte.
4. Signal: the process of determining if the detection was negative or positive.

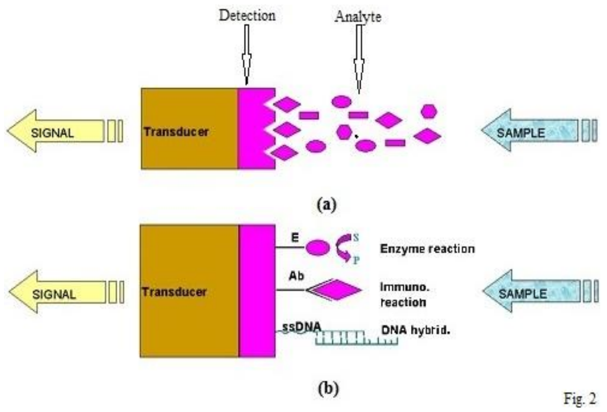

Fig. 2. Working of Biosensor

As it can been seen in Fig.2(a), there are n number of different structured compounds in the analyte sample, and in Fig.2(b), every compound is recognized by its particular substratum. Where E is enzyme, Ab is the antibody and ssDNA is the single stranded DNA.

Thevenot [7], Vo-Dinh and Allain [8] categorized biosensors based on their transduction process and the bioreceptor type, and can be divided into several categories, such as electrochemical, calorimetric, piezoelectric, thermal and optical biosensors; enzymatic biosensors, immunosensors, genosensors, and microbial biosensors respectively.

Palchetti and M. Mascini [9] also categorized biosensors based on signal transduction into six basic groups: optical, mass, electrochemical, magnetic, micromechanical and thermal sensors.

B. Generations of Biosensors

Based on the level of integration i.e. based on the method and degree of the attachment of the bioreceptor to the transducer element three generations of biosensors have been defined [10]. In generation 1, the response is generated by membrane-entrapped bioreceptors. In generation 2 mediator generated response occurs, specific mediators that improve the sensitivity for response are used. In generation 3, the bioreceptors are directly immobilized on the sensor electronic circuit to generate response.

The following is an abstraction of biosensor classification is based on transducer and bioreceptor type [10].

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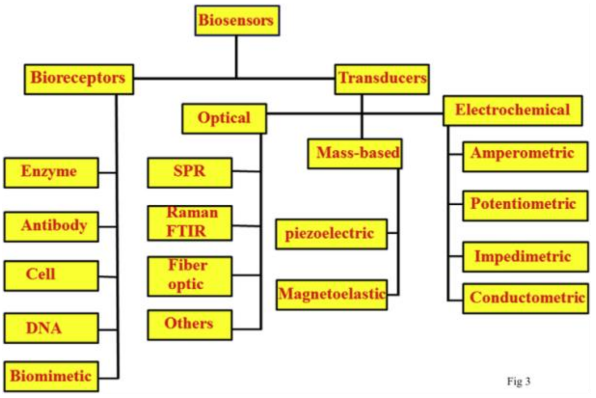

Fig. 3. Biosensor Classification

C. Applications of Biosensors

Clinical applications: cardiovascular diseases, cancer diagnosis, glucose monitoring; **Veterinary applications:** detection of meat pathogens, drugs in swine, determination of IGg in bovine milk; **Agriculture:** vitamin analysis, antibiotic detection, histamine analysis, heavy metal detection, pesticide and herbicide concentration; **Biomedicine:** bacterial detection, viral detection, parasite detection, toxin analysis, blood factors, congenital diseases [10]; location and proximity sensing, patient vital sign monitoring, at-home monitoring [11]; body movement for physically challenged persons, patient monitoring in disaster situations [12].

III.MARKED INNOVATIONS IN BIOSENSORS

The first innovation in the field of biosensors was the development of a glucose monitor. On 15 April 1956, Leland C Clark gave the Clark Oxygen Electrode using a permeable membrane. Later building upon this previous innovation, he gave a fully functional Enzyme Electrode in 1962 for detection of glucose concentration in blood, which used glucose oxidase as the permeable membrane for the electrode. It was not unto 1975 that the Clark's idea of biosensor was commercially available. The Yellow Springs Instrument Company launched the first biosensor for glucose analysis. Until 1977, many innovations in biosensors were underhand and many different biosensors for analysis of various biological compounds were being invented, but still the term biosensor was not coined. Finally, Karl Cammann in 1977 gave the term "biosensor".

A short summary of the evolution of the biosensors has been given in the below section.

The potentiometric biosensor for the detection of urea was given by Guilbault and Montalvo in 1969.

In 1970, ISEFT (ion-sensitive field-effect transistor) was invented by Piet Bergveld, which was used for the measurement of pH of a solution.

In 1975, Dietrich W. Lubbers and Norbert Opitz gave the fibre optic sensor for the measurement concentration of gasses in a sample, based on the principle that different gasses emit different colours on being excited by the monochromatic light. In the same year an immunosensor was developed.

The next remarkable innovation in biosensors was the creation of wearable pancreas. Clemens et al. in 1976 integrated the electrochemical glucose sensor in a "Bedside artificial Pancreas" later marketed by Miles as the Biostator Glucose-Controlled Insulin Infusion System.

John I. Peterson, Seth R. Goldstein in 1980 gave the fibre optic pH sensor capable of being implanted in tissue for physiological study blood oxygen and other gases.

1982 gave the fibre optic biosensor for monitoring of glucose.

1984 gave the amperometric biosensor again for monitoring of glucose.

In 1987, MediSense ExacTech launched the blood glucose biosensor.

In 1990 Pharmacia AB launches the first BIACore device based on Surface Plasmon Resonance, in further years various new versions of BIACore came which studied various molecular interactions.

In 1992, Abbot labs introduced i-Stat, which was a portable handheld blood analysis device which could study blood gasses, glucose level, troponin etc.

1996 development of glucocard- a vital blood glucose sensor.

In 1998 blood glucose biosensor was launched by Roche diagnostics.

In 1999, Haruhiko Asada et al. from MIT developed the pulse oximetery Ring sensor to mainly measure pulse, but it could also measure skin temperature and blood concentration.

In 2000, Hitoshi et al. gave a thin film glucose biosensor.

In 2002, Gerard et al. founded electrochemical biosensor.

In 2003, Sungmee Park et al. developed the Wearable Motherboard, a Smart Shirt.

In 2006, Dittmar et al. developed a Brain Core Temperature sensor.

In 2007, Ekanayake et al. created a nanotube array based enzymatic biosensor for glucose analysis.

In 2008 HLAB-2020 biosensors was developed by Hans Technologies for detection of E.coli and other food allergens.

In 2010, Nalzena et al. developed a Smart Glove that could measure electrodermal activity.

In 2010, Mathew Gluckbserg et al. created Raman Biosensor for Multianalyte Detection, which was used for in vivo glucose, urea and lactic acid analysis. In the same year, Frederick Balagadde developed Bio-Lab on a microchip, a biosensor that was capable of detecting viruses and even the HIV. The sensor is based on microfluidicds detection technology. The Bio-Lab is a palm size miniature sensor, which is capable of replacing a full functional diagnostic laboratory. The chip is capable of diagnosing up to 100 patients and the detection time per person is only 4hrs.

In 2010, Dr. George Whitesides (Harvard University) gave a biosensor that was as small as the size of a postage stamp. The biosensor came to be known as postage stamp lab-on-microchip. The biosensor is a simplistic sensor

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created out of paper and a water repellent polymer. Based on microfluidics, they can be used for bio-compound detection in blood or urine. An example is the home pregnancy tests.

In 2010 [13] a wearable Body positioning accelerometer was created to monitor patient activity at night.

In 2010 [14] a wearable device to monitor the heart rate, body temperature, pulse rate and body movement was given.

2011 [15] development of a wearable wireless ECG monitor

In 2011, Genera Healthcare created the BIACore Q biosensor for vitamin and food containment.

In 2011 [16] wearable shirt loaded with sensors for measurement of heart rate, respiration rate, ECG and body movement.

2011 [17] Wearable wristwatch like sensor capable of monitoring body movement and body pressure with a fall detection system.

2012, [18] On-body body (tilt) positioning sensor to monitor the patients' posture for reduction of bedsores.

In 2013, Jack Andreka a high school student invented an out of box biosensor, which would cost only 3cents. The biosensor was capable of determining 3 kinds of cancers (ovarian, lung and pancreas) in their early stage. The biosensor was 400 times more sensitive than the current technologies. The innovation works on antibodies to get coupled with carbon nanotubes to react with a certain protein. Another microfluid sensor develop by Andreka and Chloe Diggs could detect pollutants like mercury, lead, atrazine, copper, cadmium and glyphosate, and costs only a dollar with the detection time of 20minutes.

In 2013 Yao and Zhu created multifunctional stretchable sensors capable of strain, pressure, finger touch and other body motion monitoring.

In 2014, Ronald Davis et al. founded a biosensor based on metal insulator transition point sensing mechanism for label free molecule detection. In the same year, Lawrence Livermore National Lab developed a biosensor LLMA- Lawrence Livermore Microbial Detection Array that was capable of microbe detection for a sample within 24hrs. The biosensor is able to detect about 2000 viruses and 900 bacteria. From them some enhanced versions of LLMA came that were able to detect even large number of pathogens.

In 2014, Dr. Brennan Splegal et al. at UCLA wireless health institute developed a surveillance biosensor called AbStats, which is a non-invasive acoustic gastrointestinal surveillance biosensor. It was made to monitor the intestinal surgery patients which could develop post-operative ileus, a condition where feeding at an early stage could cause complications in the patient. The sensor determines the perfect the perfect time for the feeding process to start.

2014 [19] gave Parkinson's disease monitoring system.

In 2014 Ducere Technologies Pvt. Created a smart shoe linked by Bluetooth able to trace route, location and calories burnt. The shoe is linked to Google Maps that gives an alarm on deviation. In the same year, Mitcoin developed OpenGo an insole pressure distribution measurement, the data can be real-time monitored and stored too.

In 2015, DNA Medical Institute developed rHEALTH (Reusable Handheld Electrolyte for Lab Technology for Humans). The biosensor is a portable system that performs blood tests using only a single blood drop. The device is capable of diagnosing flu to Ebola.

In 2015, Wahoo Fitness created TICKR s heart rate monitor, which can be chest strapped, communicates with Bluetooth and is compatible with both iPhone and android platform.

In 2016, Cleveland clinic developed a frictionless non-invasive remote biosensor for round the clock glucose monitoring. The patients and healthcare personnel can be notified at the same time it detects any anomaly if found in blood glucose concentration.

In 2016, Tothil et al.[20] created an optical detection device for glucose monitoring using 3D printed microfluid technique.

IV. LEAP TO WIRELESS TECHNOLOGY

Till the 2000's the innovations that took place in the field of healthcare biosensors was just limited to the development of independent electrodes which were capable of recognizing and monitoring only a single bio-molecule from a solution. The new revolution in the healthcare field paved the way for integrating various primordial biosensors and electrodes into devices that were beginning to be used in diagnostic healthcare. The healthcare equipments like heart rate monitors, EEG, ECG monitors; medical imaging like USG, MRI, PET scans, CT scans etc. were created to be wired (still wired machines are being used till date in places where new technology has not reached). These instruments were attached to the patients by wires and were mostly very much bulky when to be moved. Whenever the patient had to be moved, all the machinery had to be disconnected and later on reconnected with the patient. This caused a great deal of discomfort to the patients with even pain sometimes, and was of course, a wastage of time and labour. In addition, the deployment of these instruments mostly localized the mobility of the patients, the patient could not move until the tests were done or until the patient was discharged from the hospital. Taking into consideration the health status of a person at that time, the mortality rate was reduced, diagnosis became easy and fast. Though these inventions were unparalleled and unmatched at the time of their usage but there was the limitation that the patient became bedridden for a period.

In addition, another important aspect of these wired healthcare systems or devices was that they were available only at a healthcare centre. As it is true that accidents are unpredictable and can happen anytime and anywhere, it would have been better if the healthcare personnel reached the spot on time and moreover that the diagnosis should get started immediately after the accident occurs.

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However, the patient monitoring is delayed until an ambulance arrives on scene and in remote and rural places only until the patient reaches the facility. This result in increased mortality rates- the death that could have been avoided.

For today's economy, the cost that a person has to pay for the healthcare facilities has increased drastically. Even if a person is insured, the cost is way more to bear. According to WHO 2015 study, a 1.8% of population have their healthcare cost to be much more than one quarter of their normal expenditures, while 6% population fall below poverty line. Another cost factor is the implementation cost, the implementation included the cost of the machinery, the cost of the wiring, the energy consumption cost and the linking cost. If compared to today's wireless technology all these cost factors have been drastically reduced.

These three factors are the driving forces behind the transition from wired healthcare to wireless healthcare. However, another factor, which is the third greatest cause of death, has been shadowed. Medical error- Sometimes in the news we heard that a death occurred due to medical negligence. It may seem way off case, but the number of deaths in only US has been determined as 251,454 (WHO), so how many cases would be there over the whole world. For medical error, if an action had been taken differently it could have resulted in a life being saved. The primary cause of medical error is the rate of diagnosis- if only the disease could have been detected earlier, if only the doctor had decided the patient to be shifted to the ICU earlier [Vinay Prasad]. Sometimes the reports of patients are mixed up resulting in unwanted complicacies, a patient of toothache being treated for cancer. Not only sometimes, the prescriptions are unreadable, leading the druggist to mistake one medication with other [HealthcareItNews]. In ScienceBlogs article a whole discussion about these medical errors has been given.

The whole technology leap is going with the wireless technology, and the people, the end users, discard one, which does not modify itself to the changing world. Therefore, it is obvious that healthcare is also modifying accordingly to the wireless technology. By adopting wireless technology, the healthcare field has transitioned to new levels.

The first listed discussion about wireless healthcare was done by Thomas.G.Zimmerman [21], in an article from 1996, named the technology Personal Area Network (PAN). Thomas G. Zimmerman headed the group working on PAN in Massachusetts Institute of Technology in 1990. Mike Hawley's Personal Information Architecture Group and Neil Gershenfeld's Physics and Media Group, both at the MIT Media Laboratory, ascertained the development of the Personal Area Network (PAN). Hawley's group needed a means to interconnect information contained by appliances located on the human body and Gershenfeld's group had been working on finding position measurement by using electric field sensing. Both of them realized that if electric field used for the position measurement would be modulated, they could send data through the body. Their research had revealed a new means to perform communication using electric fields leading to wireless healthcare networks. Many researchers have submitted their work concerning the wireless healthcare networks and the consequences were- Wireless Sensor Networks, Body Area Networks, Body Sensor Networks, Wireless Body Area Networks, Wireless Body Sensor Networks, Body Centric Wireless Networks. Some authors have termed Body Sensor Network's to be a branch of Wireless Sensor Network [22], Wireless Body Area Network to be a part of Body Area Network and Wireless Body Sensor Network [23]. Van Dam et al. in 2001 coined the term WBAN. Though there are various names but the foundation stone is to transform and modernize the healthcare monitoring procedure and enhance the quality of life by providing continuous, real-time and ubiquitous healthcare monitoring using miniature low powered and body centric devices. The acceptance of Body Sensor Network would guide a revolution in healthcare, transforming the whole medical perspective [24].

IEEE 802.15 Task Group 6 was launched by IEEE [52] in November 2007 to develop communication standard optimized for low power devices, and operating on, in or around the human body to serve a variety of applications including medical and consumer or personal entertainment and other."

The current motivation for these wireless healthcare facilities are the smartphones that are used by almost every person today. The researchers are integrating the telecommunication technology (3G, 4G) [25], Wi-Fi, WiMAX, ZigBee, PAN, RFID's together for use in healthcare. Medical devices may they be wearable devices or in-body implants are becoming more prevalent in the lives of the people. Now a days, it seems a common practice for people to carry a varied number of computing devices, that range from smart phones to i-pods to digital cameras, they do also carry or wear devices to measure physical activity, to interact with entertainment devices, or to monitor their physiology.

There are wrist gears that have taken up the work of smart-phones, heart rate monitors that runners wear while running so that heart rate measured. Many more such devices and systems have been proposed or developed. These unobtrusive, functional, easy to-use wearable [26] devices make the health monitoring possible on a periodical level at an unparalleled detail height. Wireless connectivity enables interaction with other nearby devices, the automatic sharing of sensor data with a social-networking service or a user's Personal Health Record (PHR) system or an Electronic Health Record (EHR) system for review by a health care provider. More so, as the world population grows, it will become increasingly

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necessary to use these technologies to monitor, diagnose, and treat individuals.

The whole wireless communication paradigm is facilitating the shift of the designing these biosensors too. As the number of biosensors gets increased, and communication between them starts, a need for new addressing scheme would be seen. IPv4 would not be able to address all those devices, and cannot give each device a unique network address. IPv6 is coming to rescue by providing address space for each new biosensor introduced and are now designed accordingly to support the new communication protocol. The IPv6 can provide 2128, or approximately 3.4×1038 addresses 7.9×1028 times as many as IPv4 making a haven for the personalised biomedical healthcare devices.

V. LITERATURE SURVEY

Clark and Lyons [27] had in intriguing idea of incorporating the enzyme glucose oxidase in constructing an electrochemical sensor for monitoring of glucose level in blood plasma. Their work describes an electrode which is formed of a semi permeable membrane, which is able to trap glucose within an enzyme solution. The presence is determined by the change in electrode potential when glucose reacts to the enzyme. This work had produced a general glucose sensor, which further introduced the idea of coupling enzyme with signal transduction in making finer sensors.

Wilson et al. [2] The author precisely enunciates the changes that the sensors would bring in the healthcare dimension, where sensors can be used in both medical and non-medical industries. The work has elucidated some examples of biosensors and devices that had been used in healthcare, like a subcutaneous device for glucose monitoring, biological weapon detection, pathogen detection, etc. The author is determined that the biosensors would change the future healthcare in the coming 10 years. The sensor technology changes are becoming prominent in hospitals where laboratories are becoming redundant, home healthcare dominating automatic drug delivery and so on.

Cullum et al. [28] This article has listed and documented the basics and the development of the nanosensors. The article in detail describes the process of nanofiber fabrication i.e. the process of creation of these nanosensors. The article also describes the chemical and biological nanosensors. An integration of nanofibers to biosensors and the revolutionizing of cell biology has been advocated. The article has been reviewing the similarity in the purpose of nanosensors and biosensors for intracellular bioreceptor measurement.

Vo-Dinh et al. [29] The article has formed the basis for their book "Trends in Biotechnology". This review article has given the trend of development of biosensors and biochips for medical application. The article has discussed the structure and working of biosensors and the kinds of bioreceptors and transducer techniques being used. The work describes the integration of multiple biosensors on a single chip (termed biochip) that could be able to monitor a number of biological compounds. The work concludes that for a true healthcare system there is need for a proper integration biochip for users with no technological information and updates.

Vo-Dinh, Allain et al. [8] The authors have ascertained that from the initiation, human beings have been using sensing mechanisms for bioanalysis using the five senses. The body of an organism is best at recognizing any foreign element, the factor that various researchers have been exploiting from time to time. The work further defines and classifies the biosensors by the bioreceptor type and the transducer type. The work in detail describes various kinds of bioreceptors. A listing of optical biosensors as a promising bio-analytical tool has been given, also promotes the need of an integrated biosensor technology that would change the healthcare scenario and even naïve users could be able to operate the technology. The work also lists the biomedical application of the biosensors in various disease recognition processes.

Bassi and Knopf [30] discussed the developments in technology by rapid evolution of information technology and the miniaturization of devices. The biosensor technology is now moving to smart biosensor technology that is creating a place in healthcare and medicine. The article has proposed new directions of research for biorecognition and signalling, sensor designing, nucleic acid sensors. They had variedly discussed the impact of biosensors on healthcare facilities. A shift in the biosensor paradigm has been from being just used as analyte measurement and analysis to nanosensors. The biosensors have termed to be smart and compact devices for real-time healthcare prognosis and diagnosis.

Waldman et al. [31] have highlighted the importance of individualization of healthcare that can be in reach to every person. The article professes the importance of real-time prognosis of diseases, as time is the deciding factor in diseases detection. Implantable biosensors are now seeming to be the future of healthcare. These new generation biosensors need innovative wireless data outsourcing, data integration, biorecognition and telemetry. The article emphasis on need of the fields of medicine, engineering, chemistry, law and enforcement to come together to improve the sensor technology.

Ajami and Teimouri [32] The present healthcare has been seen to be a costly and time consuming affair, where the recognition of an ailment is not 100% possible and accurate. The advances in wireless communication, information technology, MEMS, sensors and biomedicine in the past 10-15 yrs has led to tremendous innovations in biosensors, mainly in the area of wearable sensors. The

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wearable sensor market is estimated to touch $70 billion by 2025. The article mentions biosensors, telemedicine and has listed various researches for wearable biosensors and their applications.

Baldus et al. [33] came up with the idea of applying the concept of sensor networks healthcare fields. They actually constructed the Wireless Sensor Network for healthcare. They have given the overall system architecture, the network set-up procedure and the protocols for communication and association between multiple sensors. They had also described the functional architecture of the network system. The sensor communication works via an infrared interface. Their prototype has been validated and implemented by University of Berkley, with Tiny-OS as the operating system.

Dr Jo Twist the present CEO of Ukie and a former technology reporter for BBC News gave a more informal definition of Body Area Networks in her article titled "When technology gets personal: Inanimate objects will start to interact with us: we will be surrounded - on streets, in homes, in appliances, on our bodies and possibly in our heads – by things that "think". Forget local area networks - these will be body area networks".

Jamil Y Khan et al. [34] have comprehensively defined the WBAN and its medical applications. Described the implementation architecture, WBAN hardware, sensor design, network design techniques, discusses wireless networking standards. The issues and protocols used have been variably discussed. They have also given a multi patient monitoring system.

A. Abidoye et al. [35] the wok has highly advocated the use of wireless sensor networks for future healthcare management. The WSN contain sensors that can communicate either according to an infrastructure or on ad-hoc basis. If the sensors are deployed on, or near the human body the network they form has been stated as the Wireless Body Area Network and if used for biomedical applications then the network is called Wireless Biomedical Sensor Network. They have proposed a system architecture where all the sensors send their data to the Medical Super Sensor (MSS), which is then forwarded to the Intelligent PDA (IPDA), which has the critical feature of prioritization of data transmission. The priority scheduling is determined by the current medical state of the patient and works on IPDA only.

Santosh Kumar et al. [36] The mobile health has been stated to convert the mobile communication devices to a user's personal lab which would be able to monitor the health parameters, the exposure to environment etc., continuously and in real-time. mHealth involves bio-molecule sensing, bio-electric sensing and medical imaging. An overview of mHealth systems has been given which comprise of the layers of body sensors, the smartphones and the backend sensors. A discussion of the security and privacy concerns for the system has also been given.

Ghafar-Zadeh et al. [37] The Point of Care devices embedded with the wireless technology is driving the industry. These Point of Care wireless devices are continuously being used for the parameter monitoring. The work describes CMOS as the finest contender for the Point of Care biosensor diagnosis. The work gives a description for implantable biosensors, wearable biosensors and handheld biosensors. The work transitions the use of implantable devices from prosthetic organs to implantable diagnostics. The work has discussed the electrochemical biosensors as the best contender for wearable biosensors and its integration with CMOS technology to develop a novel biosensor for Point of Care.

Anas Bouayad et al. [38] the work describes the usage of WBAN to integrate telemedicine with automated data collection and delivery for the creation of solution for remote monitoring of patients. The work has been modelled and simulated providing a prototype with a coordinator node and 10 sensor node for patient monitoring. The work has also discussed WBAN system for patient interaction, monitoring applications for healthcare personnel, healthcare authority for security enforcements and cloud for data storage.

Maguluri et al. [39] the authors have developed an android prototype application for real-time monitoring and evaluation of physiological parameters of a user. The prototype is combining WBAN with Android smartphones. The primary data processing is done by the sensors themselves, the data then is sent to the smartphones via Bluetooth for secondary processing. The result can be viewed on a GUI and is also sent to the medical servers for healthcare personnel viewing.

Venckauskas at al. [**40]** the work has proposed an IoT-based prototype for personalized healthcare monitoring. The work attributes the diversity of the devices, their protocols, integration with communication network and mode of usage being the utmost factor for the challenging designing of the healthcare systems. The proposed prototype is a stack based framework that emphasizes for design automation.

Ghamari et al. [41] the article is a review article that has listed the previous developments, achievements and limitations in the current miniaturized sensor communication technology to support the apparent development of WBAN for healthcare management. The work has described the e-healthcare system architecture of being 4 layered- Ban Layer, Interaction Layer, Decision Measuring Unit And Healthcare Services. Various wireless communication technologies like Zigbee, Bluetooth, Classic, Z-Wave, BodyLan etc. have been

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given. One of the promising wireless communication technique being the IntraBody communication technique which advocates the use of the approaches of Ultrasonic Communication, Galvanic Coupling and Capacitive Coupling instead of regular RF transmission and communication.

S. Tennina et al.[42] proposed WSN4QoL technology is a new WSN based technology which exploits the network coding mechanism admitted to achieve energy efficiency for e-health application. The architecture for e-health has been divided into intranet, extranet, internet, core data systems, telecommunication and hardware. The work describes the sensors and the limitations they impose. The WSN4QoL technology also overcomes these limitations. The work has presented a list of healthcare projects that have been implemented.

Hanson et al.[43] stated the BASN, the application areas, requirements for BASN, the Networking structure, sensor design and signalling process.

Min Chen, Sergio et al. [44], Arif Isikman et al. [45] have termed BSN and BAN being the same. They have enlisted the differences between BAN and WSN, the patient monitoring and the sensors used for monitoring and advantages of WBAN have been enlisted. BAN system architecture, communication layer protocols and the radio technologies and the issues have been discussed. A comprehensive study of various projects and issues has also been done.

Benoit Larte [46] has described as WBAN being also known as BASN or BSN. The work has enlisted differences between WSN and WBAN. Described WBAN's application for patient monitoring, devices used for WBAN communication, the requirements and challenges. The security issued has been variedly discussed with the sensor positioning and underlying projects.

Aashima et al. [47] in their review article about WBAN have described of WBAN being composed of wireless sensor nodes that can be used in real-time health monitoring. They have also mentioned architecture for WBAN, the requirements and issues, the MAC layer protocols.

Sergio et al. [11] have categorized wireless body area sensor network as a subcategory of WSN for ambulatory health monitoring. They have presented at-home wearable healthcare monitoring of patients, they also presented a handoff protocol which works on a two tier architecture and can improve the channel capacity for data transmission.

Park et al. [48] have listed the technology as the driving force behind healthcare and have developed a Wearable Motherboard for addressing the healthcare challenges. The authors believe that technology can minimize the loss of lives and can also create a balance in the proportion of increasing healthcare cost. The Wearable Motherboard they developed is a lightweight, customizable, wearable and comfortable Smart Shirt which has been used for the vitals monitoring.

Crean et al. [26] have done a review of the wearable sensors for healthcare monitoring and determines the wearables to be a healthcare solution. The article has given a background study of sensors then enlisted the requirements for the creation of wearable sensors. The work has focused on leveraging the areas wireless technology and electronic textiles in creating of wearables. A summary of various wearable sensors , projects under held for smart textiles is given. Wearable sensor issues have been variedly discussed with design, cost and security and privacy included. The application of wearable sensors in fields of electronic textiles, biological and chemical sensing, motion sensing has been given. The work has also defined the wireless body sensor network, its architecture for healthcare implementation.

S Warren et al. [49] gave an overview of the infrastructure for security and interoperability in WBAN. They had analysed the work undergoing at that time in Kansas State University (KSU) and the University of Alabama. KSU was developing wearable health monitors based on Bluetooth technology whereas University of Alabama was developing wearable health monitors based on zigbee platform. For security they suggested fingerprinting, RFID tags, bar codes for authentication. The communication between sensors and personal server was based on an ID number, which was valid only for a session. Also a token based authentication was proposed.

Vidya Balasubramanyam et al. [50] gave a solution for data integrity in Wireless Biosensors Networks. They have proposed an energy efficient data integrity security mechanism and preserve data freshness. They have determined a threat model for authentication and data freshness attack plus they have given a requisite solution for both.

Tassos Dimitriou et al. [51] listed the security issues in Biomedical Wireless Sensor Networks. They have discussed the concerns and their addressal. They have discussed the insider and outsider attacks, the security requirement and the security solution, like TinySec, Biometric methods, Hardware encryption, ECC with determining Intrusion Detection System as an important tool in minimizing threats to security.

VI. CONCLUSION

The human world revolves around quantification. Everything needs to be quantified to be examined, analyzed and endeavored with properly. Mostly every parameter is quantifiable and hence the biological

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parameters too. The researchers have developed various devices that can quantify these parameters are simply show their presence in the human body. These devices are known as biosensors short for biological sensors. The biosensors are capable of ascertaining various biological and physiological parameters like pulse rate, heart rate, iris dilation, pressure, body temperature, dissolved blood gas concentration etc. The innovation of biosensors has led to a new wave of healthcare facilities, changing the outlook from a diagnostic one to a preventive one. The biosensors have been integrated with the IoT, communication technologies and enhanced by the miniaturization and adapting the MEMS and CMOS technologies resulting in the devices that are handheld, wearable or can be implanted and cost effective.

By adapting the wireless communication technology these devices can sense the parameters and wirelessly transfer the sensed data to the personal devices or the medical servers for evaluation and monitoring. These devices have increased the quality of life and any person can take pervasive healthcare in his hands, allowing him cost efficiency, greater mobility and reduction in the need and span of stay in the healthcare facility. e-health, m-health, telemedicine, wearables, implantables are the new frontiers in the medical technology providing ubiquitous healthcare monitoring, real-time feedback and remote monitoring. The work has advocated over the use of wireless technology in healthcare field and discussed Wireless Sensor Networks for healthcare, Wireless Body Area Networks, Wireless Body Sensor Networks, and Body Area Networks, which have the same theme of applying of wireless technology in healthcare field. The area is ever-growing and far more innovation can been seen.

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