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Amalgamated Fault Tolerant Smart Sensors: Survey

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***Abstract*— This paper gives the study on various sensors available in the market and their applications in different fields. As in our daily life there are various dependencies on the sensors rising from the beginning of the day start to the end of the day. there are various sensors manufactured based on the need and their application for example the elastic materials are used in fabricating and manufacturing the sensors used in the medical field for the measurement of parameters like Heart rate, PH factor, temperature so on. Whereas the sensors used in the food processing industries sensors are used to measure the parameters like temperature, humidity, etc but these sensors need not be flexible or the size is not a concern. Along with these there are many more applications of the sensors with the growing trend of smartness for eg. The upcoming smart cities depend on these sensors where each individual house would be equipped with various and different types of sensors. The sensed data from these sensors needed to be communicated to the concerned people hence to do this monitoring system with embedded systems for analysis use of portable sensors play a vital role in monitoring the various parameters need to be measured and corrected, theses sensors are fault tolerant and has high accuracy to the senses data and indicates the malfunctioning of the body parts. Here we are classifying the sensors and the designs based on the materials used for the particular applications and their design and here the communication of the sensed data is done using the WSN. These sensors are fault tolerant, accurate, and reliable..**

***Index Terms*— Amalgamated, WSN, Sensors, Physiological parameters, fault tolerant.**

I. Introduction

With the intervention of the sensors to the human practical life there are various dependencies on these by the humans for their quantitative life. Previously it was taking a lot of valuable time in analyzing, monitoring and checking the human health records. With the invention of the smart sensors various house hold devices are also kept under controlling from the remote location which is of greater help to the mankind, eg.. Gas sensing [1, 2], monitoring of the environment conditions, Pharmaceutical industries, Health Systems, Food processing units etc. use the sensors for their applications .considering the monitoring of the human health in order to reduce the immediate risks of health issues before it is too late and proper precautionary measures are handled. The sensors are classified into many types out of which elastic and non elastic [8, 9] are the important classifications. The production of the elastic is fabricated using the materials which are flexible and the properties which are used need not modify their properties. The manufacturing's of non elastic are done

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using inflexible and breakable materials. The most common non elastic sensors are been designed using the silicon substrate.
If the non elastic inflexible breakable materials are used then when these are used as monitoring devices there are chances of breakage of the system due to the stress and strain applied on to those. The alternate approach has to be used in order to reduce the damage and avoid any difficulties caused to the person while using the device on which sensors are mounted. Along with these there are many more advantages added to the system in terms of cost, fabrication and maintenance so on. The sensors used here are fault tolerant they provide accurate and efficient information's regarding the health monitored by the sensors they are reliable systems [10]. These sensors can not only have made a revolutionary changes in the field of medicine along with this they are highly used in monitoring, food processing etc.Huge change has occurred with their invention as the sensors are made so that everything is on a small finger tip. In medical applications the sensors are used in the sensing of the data and communicating these data among the care takers and the family members for the continuous monitoring and to take precautions by communicating the sensed data through the cloud network using the different gateways [11]. Fig 1 indicates the health monitoring system integrated with cloud using the wearable sensors.
Health related information is gathered via body-worn wireless sensors and transmitted to the caregiver via an information gateway such as a mobile phone. Caregivers can use this information to implement interventions as needed.

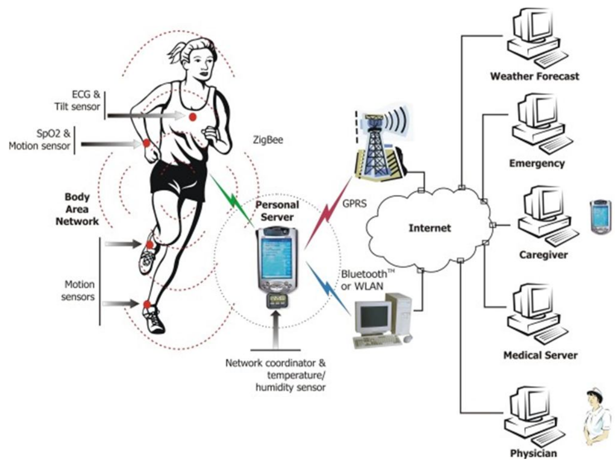

Figure1. Amalgamated health monitoring system

The sensors used in other fields other than the medical need not be flexible as they are not attached to any human who are in motion, sensors like stainless steel temperature sensors, either in the design of smooth shank or with a flange proved useful with measurement of liquid and gaseous substances, particularly in milk and brewery industries. Their design allows use in environment with high hygienic requirements. The sensors used in food processing industries are temperature sensor, water cooled transducer

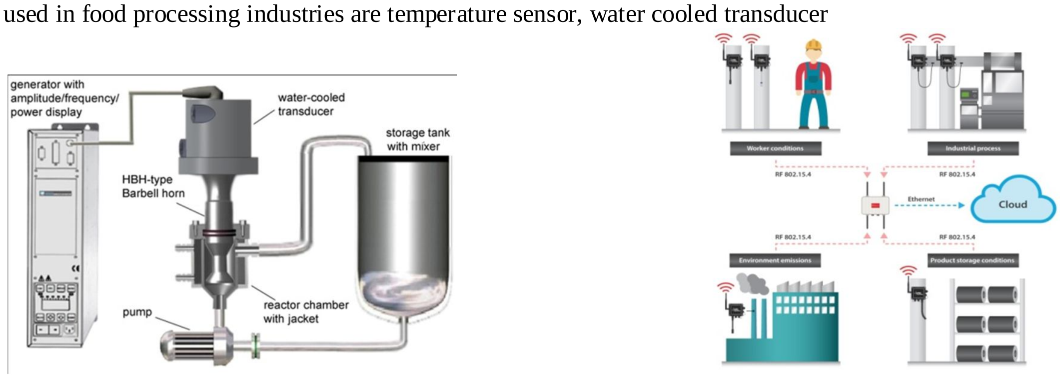

Figure 2. Sensors for Industries

The sensors are used in the smart farming also where the monitoring of the moisture level of the sand to the plucking of the fruits sensors can be employed, which reduces the man power and helps the farming easy and efficient, farmers can also use to sensors in milking the cattle's. the sensors used in farming sense the growth level and monitors the time of the pesticide demanded by the plants and require level of water level for each plant.

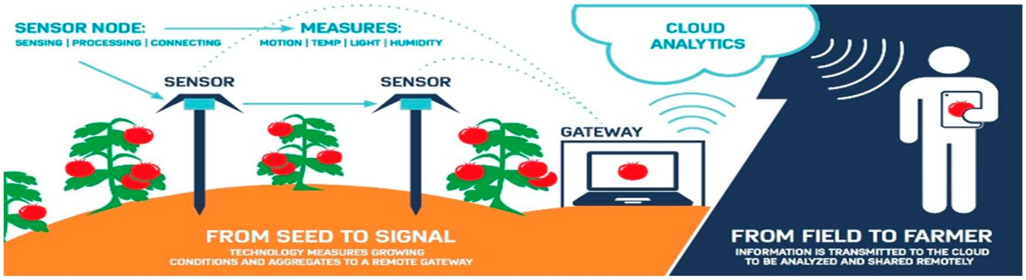

Figure 3. Amalgamated sensors for Farming

II. MATERIALS USED FOR MANUFACTURING OF SENSORS

Fabrication of the sensors is one of the important steps in manufacturing, there are various factors which are to be considered while fabricating the sensors which are needed to be taken care to one is which based on application the fabrication of the sensors needed to be done, cost of the sensors manufacturing, silicon transistors are used in organic electronic manufacturing [12]. Fig 2 shows the different types, parts of organic sensors and their usage. These types of sensors have been used in the manufacturing of thin film transistors, ionic pumps, polymer electrodes, etc. Organic and large area electronics (OLAE) [13] is a process to develop electronic devices printed in thin layers using functional inks. The substrates used for these operations are main PET and PEN due to their transparency and lower cost compared to other organic polymers. OLAE process is currently used to develop wearable health and medical devices. Use of PDMS [14, 15], PEN [16], PI [17], P(VDF-TrFE) [18], Parylene [19] and Polypyrrole [20] have been commonly done to develop flexible sensors [21] for different applications. The electrode part of the sensor has been developed from different conducting materials like carbon-based nanomaterials and metallic nanoparticles. The carbon compounds include graphene [22-24], carbon nanotubes (CNTs) [25, 26], carbon fibers [27], etc. Among the metallic nanoparticles, silver [28, 29], gold [30, 31] and nickel [32] are some of the most commonly used ones in flexible wearable sensors.

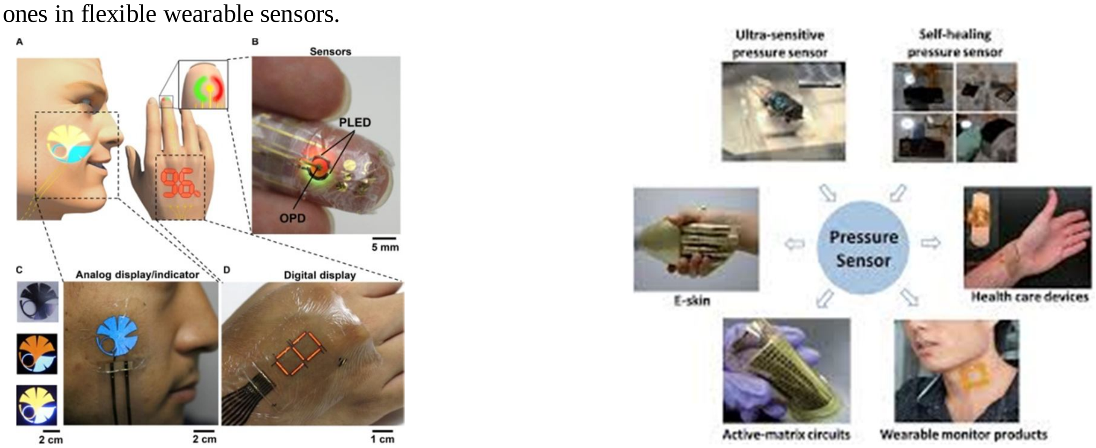

Figure 4. Different types of flexible sensors

Two main groups of materials are used for piezoelectric sensors: piezoelectric ceramics and single crystal materials. The ceramic materials (such as PZT ceramic) have a piezoelectric constant/sensitivity that is roughly two orders of magnitude higher than those of the natural single crystal materials and can be produced by inexpensive sintering processes. The piezoeffect in piezoceramics is "trained", so their high sensitivity degrades over time. This degradation is highly correlated with increased temperature. The less-sensitive, natural, single-crystal materials (gallium phosphate, quartz, and tourmaline) have a higher – when carefully handled, almost unlimited – long term stability. There are also new single-crystal materials commercially available such as Lead Magnesium Niobate-Lead Titanate (PMN-PT). These materials offer improved sensitivity over PZT but have a lower maximum operating temperature and are currently more expensive to manufacture.

Humidity sensors based on water-phase protonic ceramic materials are used widely in industry and research laboratories. The adsorbed water condensed on the surface of the materials and protons will be conducted in the formed aquatic layers. For ionic sensing materials, if the humidity increases, the conductivity decreases and the dielectric constant increase. In bulk water, proton is the dominant carrier responsible for the electrical conductivity. The conduction is due to the Grotthuss mechanism, through which protons tunnel from one water molecule to the next via hydrogen bonding that universally exists in liquid-phase water. Al_2O_3 is one of the most favorable ceramic sensing materials due to its independence of temperature at nearly all range of relative humidity from 25 C to 80 C.10 The small pore radius makes Al_2O_3 sensitive to very low water vapor pressure. Due to the electron tunneling effect inside the condensed immobile water layers, porous Al_2O_3 is a competitive candidate for sensing low humidity levels.8 In addition to capacitive and resistive sensors, more complicated sensing devices based on Al_2O_3, e.g., MISFETs (metal-insulator-semiconductor field-effect transistors), were fabricated, and some of them have very good linear response.11

III. Communication of the data from the sensors

The diagram depicts the communication of the data from the sensors to the monitoring system in the real time. There are various parameters which are to be monitored in the real time physiological parameters are significantly dependent on the sensor network used to monitor and transfer the recorded data. After processing the received data in the analog and digital division of the signal conditioning circuit, the data is transferred from the sensor node to the monitoring unit via router for further analysis. The selection of a particular communication network depends on the cost of set-up, power consumption, the number of sensor nodes, the range of trans-reception, etc. Table 1 shows the comparison of some network protocols standardized by IEEE. Among them, Bluetooth has been the most reasonable one due to its cheaper installation cost, less hardware, and high compatibility. That’s why; substantial research work has been done on developing Bluetooth integrated health care systems. Apart from the mentioned protocols in Table 1, there are some other networks with which data transmission for different biomedical flexible systems takes place. SHIMMER uses a Chipcon radio transceiver and 2.4 GHz Rufa™ antenna. For example, ECG monitoring systems have used Tmote Sky platform which has an 802.15.4 radio interface at 250 Kbps. Wireless physiological management system (WPMS) was introduced which defines carrying the real-time physiological measurement data wirelessly from the medical sensors to the processing unit. The probable applications for this technique are in drug delivery systems like chemotherapy, diabetic insulin therapy, AIDS therapy. Another network protocol called Wearable Based Sensor Networks (WBSNs), based on IEEE 802.15.4 was introduced that had different probable applications like the ECG-based system, a wearable platform for light, audio, motion and temperature sensing. Toumaz Technologies, UK devised a wireless system-on-chip integrated system where the transceiver operates between 862-870 MHz and 902-928 MHz ISM bands in European and North American countries respectively. Research projects with antennas and RF systems integrated into clothes have also been progressed working on Body Area Network (BAN) where the low powered devices would be surface mounted on the clothing in a fixed position. BAN is categorized into three categories: off-body, onbody, and in-body. Battery operated systems was another option that was considered where the developed system would be powered by a battery integrated into the system. The advantage of using self-powered systems is that the battery or the power unit of the wireless system does not have to be replaced every time the charging-discharging cycle gets over.

TABLE I. PROTOCOL STANDARDS BY IEEE

Standard	ZigBee (IEEE 802.15.4)	Bluetooth (IEEE 802.15.1 WPAN)	Wi-Fi (IEEE 802.11 WLAN)	Wi-Max (IEEE 802.11 WWAN)
Range (m)	100	10	5000	15000
Data rate (kbps)	250-500	1000-3000	1000-45000	75000
Bandwidth (GHz)	2.4	2.4	2.4,3.7 and 5	2.3, 3.5 and 3.5
Network Topology	Star, Mesh, and Cluster trees	Star	Star, Tree, P2P	Star, Tree, and P2P
Applications	Wireless Sensors (Monitoring and Control)	Wireless Sensors (Monitoring and Control)	PC based Data acquisition, Mobile Internet	Mobile Internet

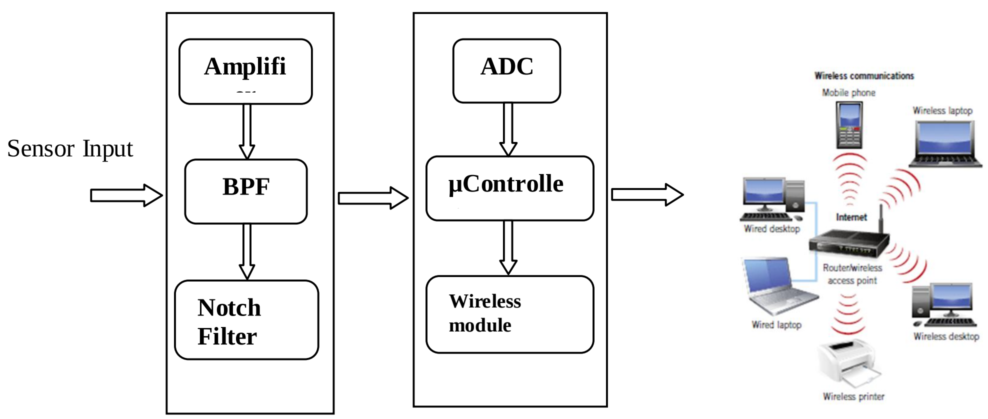

Figure 5. Transmission of the data between the systems

IV. APPLICATIONS

There are various numerous applications of the sensors in the various fields few applications are discussed in this paper in brief.

In day to day life the influence of wearable non flexible sensors is increasing. The use of these sensors depends on the application, structure and properties. In the field of medicine the sensors are used in the measurement of glucose, cholesterol. Heart rate, etc... to measure these parameters the electromechanical sensing is one of the most common method used [53, 54]. The glucose and pH sensors have been developed from CNTs [55] due to their curvature sidewalls and hydrophobic nature which provides a strong interaction through π-bonding. Some of the sensors [56] have used a layer-by-layer (LBL) structure to give it a more sturdy structure. Two kinds of polymers, PDDA and PET, were used to develop the substrate. The SWCNTs, being used as electrodes, were functionalized with –COOH group to increase the oxidative nature of the electrodes. Along with glucose sensing, these sensors provided high sensitivity towards monitoring of pH between the pH values of 5 to 9 Other type of electrochemical sensing represent the monitoring of cholesterol, which is a lipid formed in the cell membranes of animals. These types of sensors have been manufactured with both SWCNTs and MWCNTs integrated with sol-gels [57]. LBL method has also been employed with the structuring of these sensors to integrate assemble different materials in a compact way [58]. So, these types of sensors have been developed with techniques like screen printing [59], spin-coating [60], where a separate membrane of enzymes like cholesterol esterase [59], cholesterol oxidase [61] had been immobilized on the sensing surface. Pressure [62, 63] and strain [64, 65] sensors are one of the most standardized applications of flexible sensors. Different kinds of piezoresistive and piezoelectric sensors have been developed till date to monitor various physiological parameters by using them as bandages, gloves, etc. [66]. Figure 4 shows one such type formed from vertically aligned SWCNTs and PDMS as electrodes and substrate respectively. These types of sensors vary regarding gauge factor (GF) and % of the tensile and compressive strain they can sustain without reaching the breaking point. Some of the pressure sensors [67] had been manufactured as electronic bandages where the electrodes were developed by an agglomeration of two nanoparticles. The usage of more than of conductive material allowed the sensor to be used in different mediums. These pressure sensors are also used for tactile sensing [68, 69] and artificial intelligence [21, 70]. Some of the strain sensors [71] developed and tested in the laboratory had provided a change in conductivity up to a strain of 300% having a GF of 50. These sensors were based on a nanocomposite of polyurethane (TPU) and MWCNTs with nano-fibrillated cellulose (NFC) as fillers. Biomedical signal monitoring is another sector which has been worked up with wearable flexible electronic devices [72]. Monitoring of metabolites on the skin was done by sensors with ion-electron potentiometric transducers developed from SWCNTs [73]. Oppositely charged multilayered films of MWCNTs were used to establish chemoresistive sensors [74]. The detection of sodium (Na+) and potassium (K+) ions was detected using a sensor designed with Cu/PI flexible electronic layer attached to an antenna for wireless transmission of data to an Android smartphone [75]. Monitoring of saliva for bacterial infection on tooth enamel had been done using graphene nanosensors. These sensors were connected to inductive coil antenna patterned with interdigital electrodes [76]. Flexible Organic electrochemical transistors (OECTs) are another type of sensors used for testing of saliva by converting biochemical signals to electrical signals. They are developed with a PANI/Nafion – graphene bilayer film [77]. These transistors were also developed by the lamination of polypropylene films and amorphous silicon thin-film transistors on plasmaenhanced PI substrates. These sensors were used as pressure sensors and in large area sensor skins [78]. Magnetic field sensors [79] are one category developed using inorganic functional nano-membranes with polymeric foils. A linear array of 8 sensors was formed to work on the principle of Hall Effect to achieve high bulk sensitivity. A wearable electronic nose [80] was also developed with a sensor array prepared from a nanocomposite of CNTs and PEN. Hydrogel systems along with electrophysiological sensors were prepared with a spin coated and a thermally cured layer of PI on top of a layer of Poly (methyl methacrylate) (PMMA). The electrodes were formed with a bilayer of electron beam evaporated Cr and Au. These fabricated devices were applied for ECG, stress-strain measurements along with other biomedical devices. Interestingly, even alloys were used in WFS to develop biometric sensors. Thin film thermocouples like Sb2Te3 and Bi2Te3 along with Kapton substrate were used to fabricate a low power, flexible micro-thermoelectric generator. The device is proposed to be used in Ambient Assistant Living (AAL) applications.

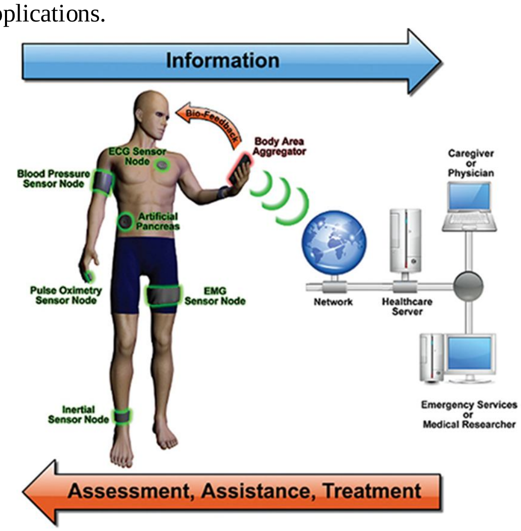

Figure 6. Sensor based health monitoring system

Other than the health monitoring the smart sensors can also be used in the monitoring of the houses where the house is left unattended by the owners where the opening of a door key can be automated by using sensor saying only when the authenticated person uses it open else don't allow the opening of the key, automatic turning of the gas when not in use by sensing the presence of the utensils on the burner, automatic water controller when no one monitors the system to avoid the wastage of the resource and they are also used to control the switching of the lights and other devices from the distance location using the cloud service. Hence the system is of great help to mankind. the parking systems also use the sensor which provides you with details of the amount of the area available for parking in that area, the loss of key or position of the key can also be detected using this sensors. The waste management at the house and colony level can be detected using the smart sensors when the dustbin is filled the sensors sense the level and sends the message to the concerned person to replace the thrash bag. Smart highway usage in the smart cities where they maintain the unexpected traffic jams and road accidents. Monitoring of environmental parameters like snow falling, forest fire detection, air pollution, Earth quake monitoring so on..,along with these they are also used in security and emergencies in factories Perimeter Access Control, Explosive and Hazardous Gases, etc in retail for Supply Chain Control, Intelligent Shopping Applications ,etc

Figure 7. Smart sensors for home monitoring system

V. CHALLENGES AND FUTURE OPPORTUNITIES

Though the advancement in the field of sensors are happening and the fault tolerant capability is increasing still there are lot of challenge which are to be addressed and taken care of, there are lot of people working for the successful correction of the error with investment of their time and energy to obtain a high performance elastic sensors in terms of sensitivity and sustainability compared to the existing ones regarding fabrication and implementation for ubiquitous monitoring. There is a huge enormous amount of data collected from the health monitoring systems and these generated data is bulk in quantity and hence these require a lot of storage space and security has to be maintained in order to process these data without losing information and without altering the collected information from the sensors. While transmitting the data from the monitored system to the recipient system there is a time delay in the transformation process hence node based techniques is used to overcome the delay in the transmission and reception of the data in the real time communication and computation technique the time delay in the system decreases the efficiency of the system and also there may be a loss of data due to the delay. The data handling should be very efficient from the central coordinating system in wireless sensors network in order to avoid the loss of data and data congestion which minimize the data corruption and altering with efficient and effect communication system the wearable elastic should be such that it is user friendly person must use the system without any discomfort. The amalgamated system helps the monitoring of the health of a patient without the segregation system which tends to occupy the large area and difficult for the person to carry the system when he is in moving these sensors should also be kept away from the fabrics which tend to alter the information of the patient without hence privacy of the information recorded is also a factor needed to be considered and taken care by the system which has to be integrated for the cloud service and the location of the sensors on the wearable device should also be taken care during the manufacturing of the system which should be such that it need not causes any damage to the system while it's in use. The data packet size tends to optimize the power consumption from the system by reducing there must be a continuous power supply to the system for the

continuous operation of. Printed electronics is another sector which can be realized for developing future wearable flexible devices. It has always been a challenge to manufacture compatible printed devices with a high throughput. The reduction in the production cost of the sensor, being one of the main motives, the idea of using abundant cheap materials to develop intelligent, smart sensors by simple printing processes is always intriguing. Some of the other factors that are considered while developing printed electronics include scalable, environmentally friendly and mechanically enhanced devices. The mass production of low-cost materials like plastics and organic substrates would also lead to a wider range of applications For example, the concept of quantum dots, where the semiconducting nanocrystals were tuned for the emission of light based on their resonating wavelength, had been exploited to develop three-dimensional (3D) printed light emitting diodes (LEDs) .
Radiation reduction measurement is the criterion which has to be considered while manufacturing the sensors for the measurement as high radiation are harmful.

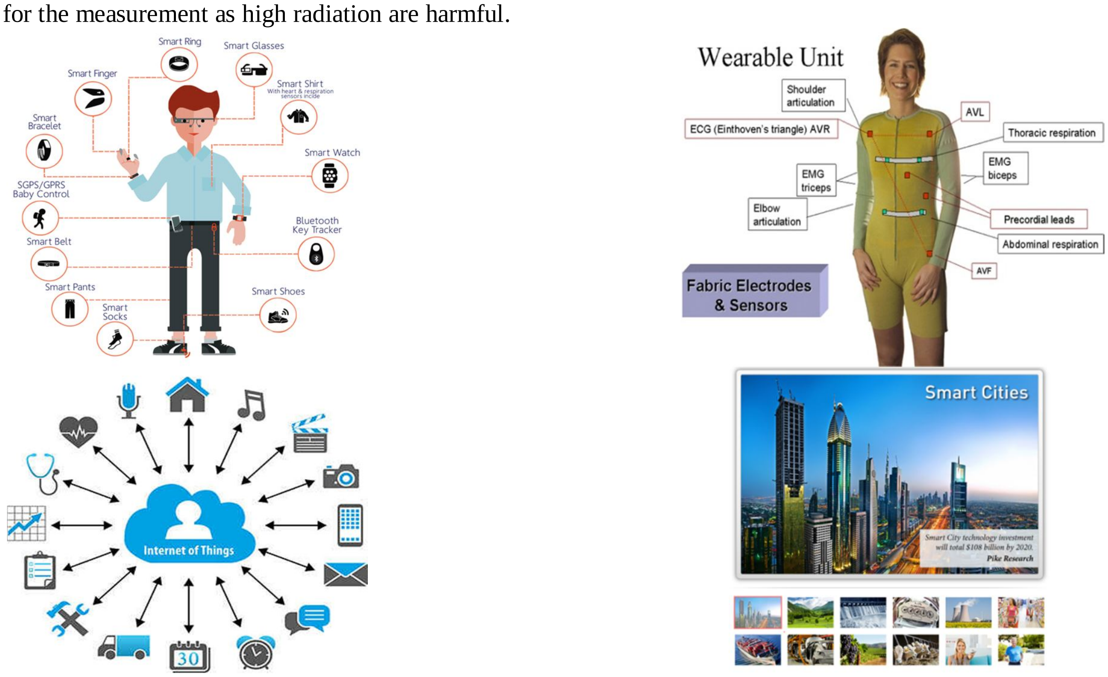

Figure 8. Usage of Sensors

VI. Conclusion

In the convention methods there were thermometer kind of devices which were used to measure the temperature where handling of these deices needed utmost care as a damage to the device may lead to improper readings and monitoring , as the days of revaluation with the intervention of wearable and portable devices this problem was reduced and further a head there are inventions going on trying to predict the health issues before the infection a minor changes would be detected and solved early. Nowadays scientist are thinking ahead and planning to monitor the thinking of a human with the devices like this in his brain. A brief Analysis on some of the prominent research works done on wearable non elastic sensors had been summarized in the paper and few applications of the sensors have been discussed which are used in the day to day system. The scope of research work on this topic is increasing every day with the growth in its market value. With the emerging new technologies like MEMS along with Nanoelectromechanical technology reduces the cost of the fabrication of the sensing system leading to various applications in future. The utilization of the existing manufacturing techniques along with upcoming ones will assist in developing new sensing systems should avail the people to have a better quality of life in near future.

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