Chapter 13
IoT Based Wearable Healthcare System: Post COVID-19

Priyanka Dwivedi and Monoj Kumar Singha

Abstract Pandemic like Coronavirus disease (COVID-19) shows that there is an urgent need for changing our traditional healthcare monitoring system which produces a lot of waste and pollutes the environment. At present patients need to visit a doctor/clinic to check-up their health. Due to COVID-19, there are risks for doctors and patients to be infected by COVID-19. There are many cases reported worldwide where doctors/nurses and low immunity power people are easily affected by Coronavirus. Many clinics, hospitals are not able to treat regular patients. Therefore, there is a need to change the system for healthcare monitoring. Different types of micro/nano, wearable sensors and devices are developed for diagnosing diseases. The advantages of these micro and wearable sensors are higher sensitivity, fast response and low power consumption. Other hand, Instead of bulky instruments these wearable microsensors can be embedded/attached with the patient and it can monitor the patient’s health remotely. Using modern computer and electronics technology like the Internet of Things (IoT) platform (which includes computer vision, Very Large Scale Integration (VLSI), big data analysis, deep learning, machine learning and artificial intelligence), it will become a real time health monitoring system. In this chapter we will initially discuss the present day’s healthcare system, followed by micro and wearable sensors used for diagnostic purposes. Further focus of the chapter will be on the electronics used for driving the sensors, devices and the collected data will be transmitted. Finally the frameworks for IoT based wearable sensors will be discussed. These IoT based wearable sensors will be a solution for sustainable healthcare systems.

Keywords Wearable sensor · IoT in healthcare · COVID-19 · Flexible devices · Smart healthcare

P. Dwivedi (✉)
Department of Electronics and Communication Engineering, Indian Institute of Information Technology, Sri City, Chittoor, India
e-mail: priyanka.dwivedi@iiits.in

M. K. Singha
Department of Instrumentation and Applied Physics, Indian Institute of Science, Bangalore, India

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13.1 Introduction

Healthcare of a human being is part of their life. A healthy person always produces better outcomes. Like season changes, human health also changes due to various effects like environment, age, immunity, virus attack, etc. Our lifestyle has changed drastically since the last three-four decades. Invention in modern technology makes our lifestyle easier and the average lifespan of human beings increases. Whenever a person becomes sick, he or she has to visit a doctor in a hospital, or a doctor visit to a patient home. According to their health condition if necessary they have to go for a diagnostics test. Till now this is the common practice anywhere in the world. But elderly people have problems visiting the hospitals due to their age. Recently pandemic like COVID-19 makes it tougher for doctors, nurses and patients [1]. There are many reports throughout the world, especially in third world countries, where normal patients are getting infected from COVID-19 during they hospital visit. Even some hospitals are completely transformed into COVID-19 hospitals. Therefore many normal activities are closed in the hospital/clinic/diagnostic centre.

There are three problems present in the modern day’s healthcare system for third world countries like India. Most of the hospital or diagnostics centres are situated in the cities and urban areas. But a large number of people are residing in the villages. They do not have any access to doctors or hospitals. They are mostly untreated and suffering from the diseases. When the patients in rural areas are in serious and critical conditions, then only they visit the hospitals. Another problem we mentioned earlier is that old age people. Due to their age they need more care and medical treatment than others. But moving from home to hospitals or vice versa is a painful memory to these people. They also need constant observations either in the hospital or at home. If these old age patients are staying in hospital then they are observed by the nurse, but at home real time continuous monitoring is not possible for this type of patient. Another aspect of the recent problem is a pandemic situation like COVID-19 which halts almost all the activities of doctors and patients in the hospital [2].

Present days natural environments and ecosystems are also declining due to rapid industrialization and it creates pollution. These phenomena also affect the health conditions of human beings in many countries in the world [3, 4]. For a healthy body, a good and clean environment is required. It is found that one quarter of health problems is due to the environment [5]. Rising healthcare problems generate solid waste which also damages the ecosystem and environment. Another problem with modern healthcare systems is use of biological, pharmaceutical products, toxic by-products from medication, infectious waste, radioactive materials and solid water waste. By-products of these are thrown out to the environment and create more damage to our health [6]. Healthcare systems generate solid waste, waste water, greenhouse gas emissions, toxic chemicals, resource consumption-water and energy. These can affect the environmental conditions such as pollution level, temperature, drinking water, humidity, etc. [7]. In comparison to consulting patients more waste is generated by the admitted patients. Waste generation by patients varies from country to country. High income countries produce more waste than low and middle
income countries per capita, but they (high income countries) have strict regulation of waste disposal. Mostly solid waste (which contains heavy metals and other toxic pollutants) is disposed of as a landfill which pollutes the soil. Wastewater from the health system (hospital) generates waste in terms of pharmaceutical products, microorganisms, heavy metals, etc. Since materials are discharged in water as an untreated substance, therefore, they tremendously pollute the ground and drinkable water resources. Greenhouse gas emission from the healthcare system is another concern for health. Significant amount of heating and cooling systems are used in the hospital. This also increases the carbon emission in the environment. A large amount of chemicals in the world is consumed/used by the healthcare industry [7]. Processing of the chemicals can indirectly pollute the environment.

When a patient comes to a doctor and if the doctor advised him/her to go for a full body check-up to find the disease source, he/she has to go under different tests. These tests are carried out in a diagnostic centre/hospital. The instruments used for diagnostics purposes are big and it needs a suitable operator to operate it. This method directly or indirectly generates pollution in the environment. Since the last few decades technology has improved drastically specially micro and nanotechnology. Nowadays micro/nano sensors and devices are found everywhere in every instrument. These micro/nano sensors are small in size and it consumes less power [8]. Similarly a recent research is going on wearable sensors and devices for the diagnostics purposes. To solve all these problems in healthcare, we can use the electronic health (e-health) technology. Presently most of the people are carrying smartphones. Using health App patients can directly know their health status. This way smartphones can act as a medium between doctors and patients. Patients (staying in remote locations) will use the wearable microsensors and devices which will collect the data in real time. If any abnormalities are found in the data, it will immediately be sent/ transferred to patients and doctors through Wi-Fi/Bluetooth modules. Then doctors will analyse these data sets and send the reports to patients in their mobile. Wearable sensors and e-healthcare systems reduce the energy consumption in the hospitals as patients do not need to visit the clinic/hospital to test their health.

In this chapter we will discuss the future of micro/nano sensors/devices and wearable sensors/devices with technology like artificial intelligence, machine learning, IoT for the future treatment of the patient. Use of these IoT enabled sensors/devices can reduce the pollution directly or indirectly and reach toward a sustainable environment. This chapter first talk about the wearable sensors and devices that can be used for sensing application and the second part of the chapter will discuss IoT for healthcare applications.

13.2 Wearable Sensors and Devices

In this part we will discuss the wearable sensors and devices used for healthcare monitoring systems. Materials used for fabricating sensors and different types of devices will be discussed.
Flexible wearable sensors and devices are also known as “electronics skin” or “E-skin”. E-skins are used for continuous monitoring of human health in real time. These e-skins are in general having very good flexibility, transparency, stretchability and stability [9–11]. Since wearable sensors are in contact with skin, therefore these devices/sensors must not be toxic. This type of sensor must have high flexibility and they should not create any discomfortability to the human skin. Few examples of the flexible sensors used in modern days are tactile pressure sensor, strain, temperature sensor and sweat sensors. There are two types of wearable sensors: physical sensors and chemical sensors.

### 13.2.1 Flexible Wearable Physical Sensors

Flexible wearable physical sensors are used to measure the physical activities and detect any abnormalities in the body like temperature, heart rate, etc. [12]. These types of sensors work on the stimulus of the body by changing them into electrical signals. Various nanostructures are engineered or functional nanomaterials are used to fabricate these types of devices. Mostly piezo resistivity, piezoelectricity, capacitance and strain mechanisms are used to measure the signals [12, 13]. Strain sensors are among the pioneers for measuring any deformation due to external stimuli in the body. For example, if the heart rate increases, then signal from the strain/pressure sensor also varies accordingly. But for continuous measurement of patients, it needs to keep the tactile information. Few research groups have included memory function in the wearable strain sensors [14–16]. According to their findings they have shown that this data can be preserved for as little as one week to six months of time [14, 15]. Metal oxide thin films are used for making the flexible Random-access memory (RAM) structures. Body temperature is an important parameter which describes whether the human being is healthy or sick. If there is any increase in temperature from normal human body temperature then it is referred to as fever. Traditionally thermometers are used worldwide to measure the body temperature. As earlier we have mentioned, this process of measuring temperature using a thermometer is not continuous. Due to pandemic situations like COVID-19, or elderly people need to measure the temperature continuously for their safety purposes. Pulse oximeter is recently used to know the amount of oxygen in blood for COVID-19 infected person. Traditionally it is small devices packaged in a hard plastic chamber where a soft part of the skin like fingers is placed and then by the principle of optics, it measures the oxygen in the blood levels. Recently a Japanese research group has used organic polymer-based light-emitting diodes (LEDs) and organic photodetector to fabricate the wearable pulse oximeter [17, 18].


### 13.2.2 Flexible Wearable Chemical Sensors

In the diagnostic centre, doctors used to take blood and by analysing the blood’s many diseases, molecular levels have been identified. This is a completely invasive method which requires many more individuals to conduct the test and analyse the results. This results in lack of the dynamic and continuous real time health monitoring. Human sweat is another fluid that also contains the molecular level information of chemicals, which can be used as an alternative strategy to diagnose the diseases and physiological state of the body [19–21]. There are different chemical compositions found in the healthy and unhealthy human beings. If a person has not good health, he/she will have different sweat concentrations which have different analytes [22–24]. By analysing these analytes within sweat we can diagnose the disease of a human body. Mostly flexible electrochemical sensors are used for this type of activity to measure the pH, Na\(^+\), K\(^+\), Ca\(^{2+}\) ions, dehydration, glucose and lactate [22]. The increase of Na\(^+\) ions in the sweat suggests the dehydration in the body [22]. Changes in Cl\(^-\) ions in sweat can be used to identify the cystic fibrosis [25, 26]. Takei groups in Japan have used the iontophoresis principle in sweat to measure the glucose level in the body. Recently a wearable sweatband was introduced in continuous mode for detecting methylxanthine drug levels in a body by sensing caffeine [27].

Some of the research groups are trying to fabricate multifunctional wearable sensors by including both physical and chemical sensors. While incorporating these sensors, they have to keep in mind that wearable sensors should not be thick and it should stick to the skin and not to cause any itchy sensation. Figure 13.1 shows the schematic diagram of multifunctional wearable flexible sensors which consist of pH sensor, glucose sensor as well as temperature and strain sensors. Sensing films of the pH and glucose sensor are mostly oxide materials like InGaZnO, MoO\(_3\), TiO\(_2\), ZnO etc. In this case ion-sensitive field-effect transistor (ISFET) principles will be used to measure the pH and glucose of the body from sweat. Similarly Ag is used as temperature sensors, Polydimethylsiloxane (PDMS) and Carbon PDMS was used

![Fig. 13.1 Schematic diagram of the flexible sensor (includes pH, glucose, temperature and strain sensors)](image)
to fabricate strain sensors to measure the heart rate. Polyimide film was used as substrate to fabricate the pH and glucose sensor and later it was transferred on the flexible polyethylene terephthalate (PET) substrate. Other sensors and devices are fabricated on PET substrate. Total thickness of all the devices is less than 400 μm.

### 13.2.3 Materials Used for Flexible Wearable Sensors

Substrates used for both physical and chemical wearable sensors should be flexible. Different substrates like PDMS, polyimide, PET, cloth and papers are used for fabricating the sensors. Different materials are used for making sensing films. It includes ZnO, InGaZnO thin-film on Polyimide substrate as sensing material of ISFET devices with Al2O3 as dielectric materials. Single wall carbon nanotube (SWCNT), silver (Ag) also used for either sensing materials for circuits for the readout data or providing electrical signals to the devices. Mostly silver nanoparticles in ink or 1D metallic nanowires (Ag), graphene, conducting polymer like Polyaniline (PANI), polypyrrole, poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS), mXenes are used as sensing materials or energy storage materials [28–31]. Thickness of these devices ranges from a few μm to 1 mm.

### 13.2.4 Techniques to Fabricate wearable Sensors

Wearable sensors do not use traditional fabrication processes. These wearable sensors are needed to be flexible and biocompatible. So, researchers have used different techniques. Printing process is the most readily available process to fabricate the devices on a large number of substrates. If any materials need to deposit as a sensing or electrical line, then the ink of those materials need to be prepared first. The size of the materials should be less than 50 nm. Otherwise it will block the nozzle orifice. Organic solvents are used to prepare the ink. We must be careful while preparing the ink so that post processing of the ink (heating) should not damage the substrate. Laser cutters are also used to cut these devices and the same system can be used to fabricate graphene as a sensing material that can be used in wearable sensors. Polyimide is an organic compound which can withstand up to 400 °C without damaging its flexibility. By varying the round per minute (RPM) in the spin coater, thickness of the films can be varied as low as 2 μm. Many wearable flexible sensors were fabricated on spin coated polyimide substrates [12, 26].
13.2.5 **Power Source for Wearable Sensors and Electronics**

Power source is required to drive the sensors, read its value and transmission of the data. Various research groups have been employed to design and fabricate wearable power sources. Mainly supercapacitors, batteries, thermoelectric and piezoelectric generators are used as a power source. Since the advancement of triboelectric nanogenerators (TENG) in the last decade many research groups have advanced the flexible wearable triboelectric generator [32]. Recently a heart rate sensor was found to be working condition which was driven by the TENG. This TENG is not only used to provide the power supply to the sensors but also used for providing power to the signal processing unit and Bluetooth module [33]. Not only this flexible organic materials are used for power generation, but non organic materials like $\text{Pb}[\text{Zr}_x\text{Ti}_{1-x}]\text{O}_3$ (PZT) film was also used for self-power TENG applications [34]. Recently Someya et al. group have developed the world’s most thinly flexible solar cells which can be used to charge the flexible batteries, supercapacitors [35]. This power source was used to drive the sensor for measuring the cardiac signal. Yun et al. have shown that their micro supercapacitors are stretchable and it can be charged with solar cells and further these supercapacitors were used to measure the arterial pulse [36]. Recently in 2020 a group of researchers in Purdue University have used polymers like gelatin, Polyvinyl alcohol (PVA) modified with NaCl and KCL to make a flexible thermoelectricity generator [37]. Thermoelectric generator is a very old concept which uses the Seebeck effect to generate the voltage. If the junctions of the materials are kept in two different temperatures, then electricity generates. Many research groups have employed thermoelectric generators for the power supply to drive these sensors and transmit the data. Table 13.1 shows the different wearable sensors that can be used for continuous healthcare monitoring systems.

13.2.6 **Implantable Devices for Healthcare Monitoring System**

Invention on biocompatible material and advances in nanotechnology makes a new room for implantable devices and sensors. This decade and upcoming decades will enhance the research on implantable devices. These devices have many applications like home security and human healthcare monitoring systems. Implantable devices are so small (maximum size of $2 \times 2 \text{ mm}^2$) that it does not create any discomfort to the human body. Table 13.1 shows some examples of implantable devices which are used to monitor human health continuously. These implantable devices are used in many physiological parameters measurement like glucose, pH, electrolytes, heart beat, etc. Some of the commercially available sensors for healthcare monitoring are also shown in Table 13.1. These commercially available devices are mainly used to measure blood pressure, glucose, lactate, etc.
| Device type          | Diagnostics                | Physical parameters | Flexible | Sensing mechanism                  | References |
|----------------------|----------------------------|---------------------|----------|------------------------------------|------------|
| Skin patch           | Heart rate                 | Electrocardiogram (ECG) | Yes      | Pressure                           | [37]       |
| Skin patch           | Heart rate                 | ECG                 | Yes      | Piezo-resistive                    | [38]       |
| Skin patch           | Blood pressure             | ECG                 | Yes      | Ultrasonic                         | [39]       |
| Sweat                | Physiological health       | OH⁻, H⁺, Cu⁺, and Fe²⁺ ions, pH | Yes      | Impedance                          | [40]       |
| Sweat and            | Blood glucose              | Glucose             | Yes      | Electrochemical, reverse iontophoretic | [41]       |
| epidermal bio-fluids| Physiological health, body electrolyte | Na⁺ and K⁺ ion      | Yes      | Electrochemical                    | [42]       |
| Patch, sweat         | Physiological health       | Lactate, pH, Na,    | Yes      | Electrochemical                    | [43]       |
| Patch, sweat         | Physiological health, blood glucose | Glucose and pH     | Yes      | Electrochemical                    | [44]       |
| Patch, sweat         | Physiological health       | Hypoglycemia        | Yes      | Enzymatic fuel cell                | [45]       |
| Wrist wearable       | Blood pressure             | Pulse               | No, but wearable | Hall measurement                 | [46]       |
| pulsimeter            | Blood pressure             | Pulse wave velocity | No, but wearable | MEMS based pressure sensor        | [47]       |
| Wearable skin surface| Blood pressure             | Glucose and lactate | Yes but lacks electronics | Electrochemical                | [48]       |
| Conductive thread on | –                          | –                   | –        | –                                  |            |
| textile              | Glucose and lactate        | Yes but lacks electronics | –        | –                                  |            |
| Implantable          | Optical neural simulators  | Brain or neural system | Implantable | Optical                           | [49]       |
| Implantable          | Respiration and bacteria detection | Saliva              | Implantable | Electrical                        | [50]       |
| Tattoo, sweat        | Physiological health       | Glycemic, glucose   | Yes      | Reverse iontophoretic and amperometric | [51]       |
| Tattoo, sweat        | Metabolic disorder         | Ammonia             | Yes      | Potentiometric                     | [52]       |
| Tattoo, sweat        | Human perspiration         | Lactate             | Yes      | Electrochemical                    | [53]       |

(continued)
13.3 **Internet of Things (IoT)**

The term, internet of things (IoT), is relatively new and introduced in 1999 by Kevin Ashton. But it was popularized in this decade only (after 2010) [56]. IoT integrates many parameters like sensing of sensors, data storage, connectivity, power, computation, protocols [57, 58]. IoT has many applications found in various places like smart cities, remote monitoring, agriculture, healthcare, etc. The advancement of information technology with manufacturing capabilities enhances the IoT operation. In this chapter we are more concerned about wearable sensors for healthcare monitoring using IoT. Till now healthcare systems in most of the countries are reliable on paper based records received from the doctors or clinics. It is very rare to share the data between patients, doctors, and clinics in third world countries. But there is a huge scope of IoT in healthcare systems.

IoT’s are real time systems as they connect sensing, storage, computation, and communication to sense physical systems and respond in real time. These systems also connect nodes with cloud or fog computing and designing chips for IoT requires a new strategy i.e., big chips are not certainly the perfect fit for fog and edge devices in the IoT domain. Since, IoT devices are cheap and are being used in various departments like healthcare, smart transportation, pollution monitoring, etc. As the number of devices is increasing rapidly, challenges are increasing and one of the primary challenges is low power consumption and performing machine learning (ML) at the device, security, and safety. Even though standardization of technical terms has not done but some of the common terminologies are given below:

- Nodes are the edge devices that offer communication and sensing.
- Hubs/gateways are devices which connect one or more nodes.
- Fog means nodes that are placed in between the edge devices and cloud.
- Cloud is used to do remote computations and for storing the data.

Traditional systems on chip (SoC) design with sensors have features like big chipsets whereas IoT device design features like low power consumption and lower device area. It is required to join both mature manufacturing and novel technologies in system-in-package configurations to make a combination of low power consumption, computation, sensing, and communication. There are several parts in the IoT based healthcare system. First we need wearable sensors, then these sensors need to read the data and send it to the machine. Machines will process these data and finally provide the outcomes. In this total process communication or networking and security plays an important role for IoT enabled healthcare systems. There are a total
three communications established for IoT based healthcare systems [56, 59]. These healthcare systems are as follows: i. People to people connection, ii. Machine to people connection and iii. Machine to machine connection.

### 13.3.1 Network in IoT

After obtaining the sensing data it needs to be transmitted to the system where it will be post processed [60]. Due to the diversity of the nature of physical sensors, especially in healthcare systems, there are many communication systems that exist. These communication systems are used either in device to device communication, device to cloud communication, etc. [58, 60]. IoT not only exists in healthcare, but also in smart cities, agricultural fields. So there is an increase of traffic volume in IoT based communication and networking systems. So some of the network requirement was established on IoT based system which includes different variables like: identifying individual objects and its connection, location of the object, security and individuality with total privacy, reliability, automatic networking, bandwidth, optimum spectrum uses and flexibility of spectrum uses, highly scalable, self-configuration and energy efficient, etc. [61]. Like many IoT based systems, IoT in wearable continuous health-care monitoring will depend on wireless technology. Two types of network available: Access network (AN) or local network and core network (CN) or global network. Access network is used to connect between physical objects and CN whereas CN is used to interconnect between other networks within CNs. Radio-frequency identification (RFID), Near-Field-Communication (NFC), Bluetooth module and low power wireless communications are examples of access networks and Mobile phones, 3G, 4G, are the core network example. While accessing or transmitting data, each person should have one unique identification number. Without this identification, IoT will not work. Figure 13.2 shows the different wireless network systems that are used in IoT based systems. Proximity and wireless personal area networks are attached with embedded sensors and devices (wearable sensors). They will transmit the data according to the programming. Then these data will be sent to doctors/nurses through Wi-Fi to the working station. For the remote people, it will use wireless wide area networks like 2G, 3G, and 4G in mobile. Then through the system protocols like App, it will send the information to concerned doctors and after analyzing those data doctors will send the report through mobile. Patients will then receive the report on their individual smartphones. Nowadays all of the smartphones have Bluetooth, Wi-Fi modules and the internet is accessible to most of the people. Therefore, a low power wireless network in wearable sensors like RFID (if the patient is in hospital), Bluetooth, Zigbee module is sufficient to send the data from a remote place to a doctor in a city using a smartphone. IoT have thus capabilities to connect between patient to machine (P2M), Device to machine (D2M), Sensor to mobile (S2M), Patient to doctor (P2D), doctor to machine (D2M), Machine to sensor (M2S) and mobile to human (M2H) [62].
13.3.2 Architecture of IoT Based Wearable Healthcare System

Framework of an IoT based system not only comprises the physical sensors or wireless network but also comprises of web technologies, controller for the sensors and power supply, system components (it consists of data collector, IoT gateway, backend facilitator, access applications), proposed applications, security model, modelling exercise, implementation details, experimental details, implementation scenario [63]. Figure 13.3 shows the schematic architecture of IoT based wearable sensor systems using mobile for continuous healthcare monitoring systems.
There are two types of sensors that can be used for healthcare IoT. One is wearable flexible sensors and another is traditional Micro-Electro-Mechanical Systems (MEMS) based wearable sensors and devices but without flexibility. Though MEMS based sensors and devices lack flexibility, they can be integrated in a printed circuit board (PCB) circuit easily. Therefore these types of devices have the opportunity to have their own microcontroller and coin types batteries which power the controller circuit and are able to transmit data through Zigbee or Bluetooth to the smartphones. Recently a flexible microcontroller circuit or RAM is fabricated on a flexible substrate by PragmaticIC. They can customize the design based on customers’ demand and applications. Mostly 32 bit microcontroller is used worldwide for IoT based applications. Intel and ARM have their own 32 bit specialized processor which is used for large scale IoT applications. For small scale applications, JAVA ME embedded (128 KB RAM and 1 MB ROM) can be used. It has its own operating system [64]. Any IoT system requires numerous numbers of communication and network. It was discussed earlier in the “Network in IoT” section. System components are another part of IoT. Sensors sense the body and then it converts it to digital form. Then these digital data will be sent through different network protocols and gateway. During transmission of data from the patient to doctor and doctor to patient needs a serious security-enabled protocol. A password for each individual and devices should be generated and TLS/SSL protocol should be followed between mobile and cloud communication. Table 13.2 shows the IoT based different healthcare systems.

| Device                                      | Application                  | Communication medium       | Method of testing          | References |
|---------------------------------------------|------------------------------|----------------------------|----------------------------|------------|
| Microphone and smart sensor                 | Voice monitoring            | Wireless, bluetooth        | App, cloud computing       | [64]       |
| RF ID based                                 | Patients disease monitoring | Radio frequency identification (RFID) | Directional antenna, softwares | [65]       |
| Biomedical sensors                          | Real time health monitoring | –                          | Sensors                    | [66]       |
| Wearable device                             | Diabetes monitoring         | Using App                  | Smartphone and smartwatch  | [67]       |
| Wearable electrocardiogram monitoring system (ECG) | ECG monitoring              | Bluetooth, 4G LTE RF       | Analog front end, BLE, cloud | [68]       |
| Sensor array                                | Diabetes management based on IoT | Internet, Bluetooth     | Blood sugar, and blood pressure | [69]       |
| Smart T-shirt                               | ECG monitoring              | Bluetooth low energy (BLE) | App, AFE chip, MCU,         | [70]       |
The Edge IoT devices can be all kinds of smart homes, smarter healthcare, intelligent transport, intelligent buildings and smart cities with different capabilities, and a large array of appliances can be installed. In the current cloud and application facilities, it is normal for such vast quantities of edge devices, as a majority of the computing, storage and networking resources of these power data centres that come from application-service providers (ASP) that operate directly with the web servers on a limited number of dispersed larger data centres [72, 73]. The same process is applicable for sensing devices also. In general, this cutting-edge cloud work is in the beginning and a lot of problems must be dealt with. There are several exhaustive analyses of the current state of research and edge cloud activities are reported by different researchers. In which emphasis was on the future main technologies such as Network functions virtualization (NFV), Software-defined networking (SDN), sensors and a new insight in a potential IoT application. Yet, security is crucial for IoT systems in the deployment as demand for sensitive data protection in applications like healthcare.

13.4 Conclusion

In this chapter we have discussed the flexible wearable sensors for IoT based continuous health monitoring systems. There are two types of wearable sensors present. One is a flexible wearable skin sensor and the other one is non-flexible like a wrist watch. Flexible wearable sensors are able to monitor health continuously. At present it has some limitations and can monitor only few things like heart rate monitoring, body analytes, pH, temperature, glucose. Flexible wearable sensors mainly used organic materials with printing and spin coating as main instruments to fabricate the devices and sensors. Even different RAM and electronic circuits are fabricated with these techniques. A wearable energy source is also under studied. Finally these sensors can be attached with different communication systems for the realization of a true IoT based healthcare system. Mostly local proximity connection with smartphones is used for these applications. Security in IoT based healthcare systems is another challenge. In future it may be possible to have an individual lab on body with IoT for day to day healthcare monitoring systems. These IoT based wearable healthcare systems will reduce pollution in the environment and make a sustainable environment for future generations.
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