Chapter 7
IoT Healthcare Applications

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Abbreviations

CGM	Continuous glucose monitoring
CYCORE	Cyber infrastructure for comparative effectiveness research
ADAMM	Automated device for *asthma monitoring*
GPS	Global positioning system
IoT	Internet of Things
PPG	Photoplethysmography
QR	Quick response

7.1 What Is the IoT Healthcare System?

IoT stands for Internet of Things. Simply put, it can connect numerous devices to send data to each other through the internet. These devices are usually embedded with various technologies, sensors or related software. The significant advantage is that the devices work without human intervention. The tools can learn through the data collected under data analytics.

IoT has found its application [1] in multiple fields in recent times; healthcare is just one of them. In the upcoming times, IoT will continue to be implemented within healthcare and is guaranteed to increase productivity and data analysis drastically. These technological advancements will enhance medical devices [2] and produce better outcomes and improved analytics, which is likely to be accomplished promptly.

Quite often, cloud technology is coupled closely with IoT technology because both require internet access. Examples of this are our smartphones and smartwatches. Our smartphones can connect to our home security systems, cars and

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kitchen appliances. Through the concept of IoT, imagine preparing a meal from your phone while driving home from work.

The healthcare-specific IoT produces a massive amount of data generated by these connected devices which hold the potential to transform healthcare. Hospital staff are overwhelmed with patient monitoring devices: pulse oximeters, CPAPs, ventilators, infusion pumps, ECG machines and the list goes on. Combining patient data from the various machines can provide a much more rich and accurate story about the patient's condition. IoT connectivity can centralize this data; it can be analysed and communicated to all healthcare [3] providers through smart technology.

There are many medicines for various health problems and conditions common man is hardly aware of in the market. Many pharmaceutical industries are working to produce genuine drugs. IoT can be beneficial in this regard. QR code or IoT infrastructures can help individuals to assess how good their medicines are. One can know about the manufacturer and become knowledgeable on how legitimate their purchases are.

IoT is a four-step process.

- IoT System Construction is an interconnected device consisting of sensors, actuators, detectors, monitors and camera devices to collect the data next.
- Data collected from sensors [4] and other technologies within these devices are in analogue form. These signals are integrated and converted to the digital format for pre-processing.
- Once the data are pre-processed, it is aggregated and standardized. These data are then transferred to the data centre or cloud.
- Finally, data are managed and analysed at the required level. Advanced analytics is applied to these data for effective decision-making.

These stages are interconnected since the yield of processing one step is the input for the following steps.

IoT also helps track the real-time location of various hospital equipment such as oxygen cylinders, wheelchairs and nebulizers. These devices are tracked with sensors embedded within, which help in tracking their location. Medical staff working from various geographical regions can be tracked in real time (Fig. 7.1).

Many healthcare specialized companies are moving towards investing in IoT intensively. Currently, be it X-ray machines or biosensors there in connectivity in most tech devices with Bluetooth or WiFi. When medical devices enabled with IoT, assist the jobs performed by health practitioners by providing them with critical data. This inclusion of IoT im-proves outcomes of healthcare facilities and reduces the burden of health practitioners. It becomes easier to monitor patients and make observations on the progress of a treatment or even housing vaccines with devices with IoT specialized in medicine [5].

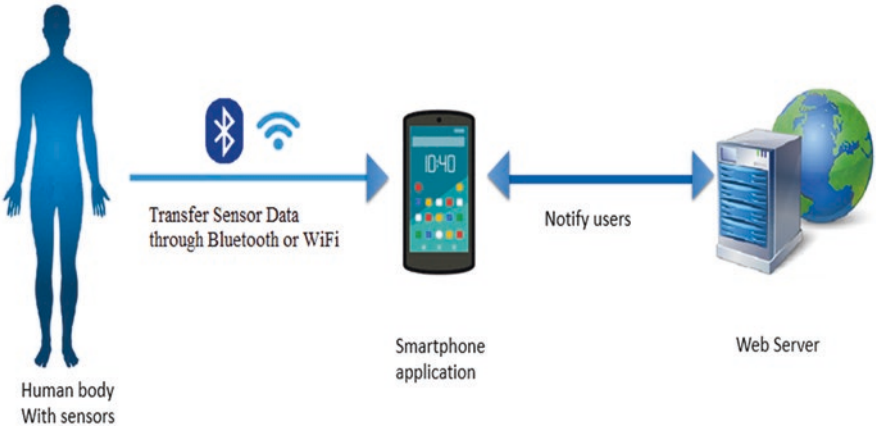


Fig. 7.1 IoT architecture

7.2 Cloud-Based IoT Healthcare Applications

Cloud-based IoT guarantees distributed-location-based services. The platform can be used to periodically collect and broadcast data. IoT is widely applied in various fields, such as the medical healthcare system. On the other hand, cloud computing offers on-demand computing resources as a service from mobile devices to supercomputers. Cloud computing is a method for large data storage and analytics. The combination of IoT and cloud computing will enable monitoring services and processing of sensory datasets.

The cloud eventually serves as the brain to improved decision-making and optimized Internet-based interactions.

Cloud computing paradigm is one of the trending topics in the recent year information technology field. It has mobility, security, efficiency, reliability and scalability advantages. Users are provided with storage, applications, services, servers, hardware and networks, which are the most demanded resources. For IoT systems, cloud computing serves as a backbone, according to researchers. Sharing of information amongst patients, caretakers, and professionals is more organized and structured with cloud computing. Cloud secures the medical records and reduces risks of these getting lost. As a result, healthcare services and applications have benefited from developing IoT and cloud computing technologies.

Authorized users can access important information for treating patients and research purpose. This integration would make information exchange simpler and cheaper between practitioners or even hospitals.

Let us understand in brief with the example of a Smart Fridge which addresses vaccine management issues. Weka developed it to deal with vaccine storage which is done at an apt temperature. Errors can lead to spoilage of vaccine. With Smart Fridge, vaccines can be monitored and stored at the recommended temperature,

from remote locations. Inventory management services are automated, which makes it easier for clinicians to stay updated regarding vaccine storage.

Health practitioners can log in and specify the vaccine needed. The Smart Fridge then gives access to the vial requested leaving the remaining inventory unaffected. Smart Fridge eliminates unnecessary interaction work that needs to be done. It also allows us to analyse the data and find trends which can be used to design vaccine programs. Smart Fridge would be highly beneficial in high-risk rural areas.

7.2.1 Cloud-Based IoT Network Architecture

IoT stronglyassociated with cloud computing, a cloud used as front end. Cloud computing provides several advantages to IoT. Cloud computing is based on the concept of allowing users to perform regular computing tasks using services delivered entirely on the internet.

Cloud-based IoT [6] has bestowed us with data collection and broadcasting services. Despite being geographically separated, the cloud has helped to access these facilities periodically. While combining IoT and Cloud, healthcare practitioners must understand how these facilities are exceptional and useful. Memory and space requirements can be minimized if an application [7] is hosted on the Internet (Fig. 7.2).

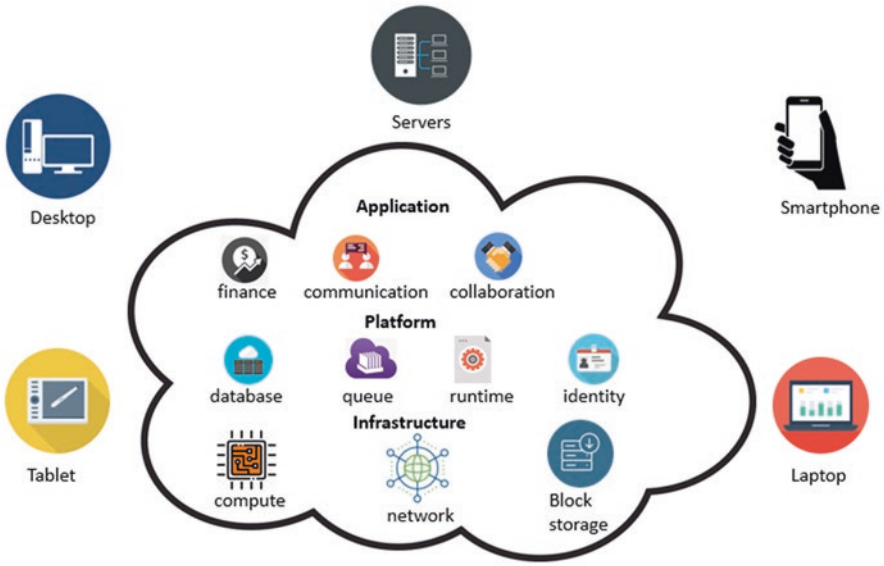


Fig. 7.2 Cloud computing

7.3 Opportunities in IoT Healthcare

Before introducing IoT into healthcare, doctors or health workers couldn't interact with patients and monitor their health conditions regularly. Treatment was discrete. With IoT, these communications are made easy and possible. The scenarios of huge hospital stay and getting admitted have reduced guaranteeing customer satisfaction.

Better outcomes are expected at much lower costs. It has always been observed that the introduction of technology with innovative strategies has benefitted business models. With improved customer engagement, asset management, cost reduction, reduction in theft possibility and customer engagement, IoT has proved beneficial for businesses and marketing in the current times.

IoT, machine learning, block-chain technologies and big data analytics, are expected to be the future trend. With IoT devices get smarter.

7.3.1 Functional Fields

Technical developers work with Arduino or raspberry pi modules, net-work connections and cable connections. Having accurate and precise sensors is very important to produce correct and reliable results. Specialists in sensor technology and integration would have to work on improving their working. Communication between various devices facilitates that data are transmitted from one location to others, storing or retrieving. It is essential to have fast communication networks [8] with a good number of participants.

The application used should be updated and maintained regularly considering the evolution of system hardware and system software. Software Development Engineers, therefore, are pivotal for handling the application. Cloud design and management are planning for efficient usage of resources. Cloud architecture [9] needs to be understood at various levels of comprehension.

Data collected from various devices and various individuals after being stored are analysed to find patterns. Data analysts have a very crucial role to play when it comes to handling big data and exploiting it in cost-efficient ways. Processing extensive data with a minimal amount of hardware is an economical idea. By making predictions using various algorithms, IoT devices can help determine conditions deviated from the normal situation. They can prove to be very valuable in life-threatening situations.

7.3.2 Non-functional Attributes

Apart from functional features, non-functional attributes are also of utmost importance. Non-functional attributes include security, reliability, privacy, scalability, adaptability and portability. These are even more crucial as failing to meet any one of them can prove dangerous and fatal.

It becomes necessary to maintain confidentiality of information such as patient details, diagnosis information, treatment procedure or any other confidential information. Not everyone can access all or part of the information. Authentication stages need to be defined. Cyber security experts need to work on the protection of information stored. Transfer of data needs to be secure. Block-chain can be an apt solution for the same considering that the current and previous systems are vulnerable.

7.4 IoT Solutions for the Disabled in Healthcare

Around 650 million people in this world are disabled. IoT can ease the lives of these people and make them more independent.

7.4.1 Smart Homes

Oneapproach can be to automate their homes. The idea of smart homes enhances the quality of living of the specially abled people. Features of their residence can be specialized for the individual's care. Various tasks can be performed by connecting devices such as speakers, oven, television, air conditioners and other electrical appliances. This would be of exceptional help to individuals with mobility impairments. Voice assistants such as Siri, Google and Alexa can also be used for controlling the house. Voice commands can be used to lock and open the doors, turn lights on and off and even adjust the thermostat. Smart lights can be used to alert deaf individuals when there are visitors at the door.

The various components of smart homes are given as follows:

- Sensors: Sensors are installed within the house to collect internal data to analyse conditions at home. They are attached to various devices, and finally, the data collected are transmitted to the IoT server with the help of a local network.
- Processors: IoT server after receiving the data processes it. There are various software designed appropriately to translate the data collected by sensors to perform necessary actions.
- Actuators: These are the components which would control the working mechanism and movement of a device or machine. The commands sent by the server are executed by performing needed action.

Fig. 7.3 Smart homes

– Smartphone App: The conditions can be handled with the help of an android app. Various devices or electronic devices can be controlled by a fixed schedule or by this app.
– Cloud: The data collected from sensors stored in a database over the cloud. The collected data could be analysed and made use of in future.

As we observe, the necessary steps, as in Sect. 7.1, are very similar to the four stages in smart homes (Fig. 7.3).

7.4.2 Travelling Made Easy

A few more ideas can ensure safety outside their homes.

There is a Crosswalk IoT system in Dutch. Sensors are embedded in traffic lights and streetlights. There is an android application that connects various individuals and tracks their geographical location. The app tracks down if any specially abled individuals or older adults are waiting at the pavement to cross the road. The traffic lights remain red and allow pedestrians movement for a more extended period to safely cross the street.

Cloud Vision API is made available to developers by Google to creating apps which can be used to design IoT devices for visually impaired people using image recognition algorithms. The device captures the surroundings with the camera and

uses this to identify objects, landmarks or places. The device can work like smart glasses where the user is to told what is around through a hearing unit.

7.4.3 Communication Made Easier

Deaf and blind people use sign language to communicate with various hand movements. This language has its grammar. Special gloves enabled with sensors can be designed to track hand motion and record it as electrical signals. An accelerometer is one such sensor that can be used to find the hand's acceleration by considering the x,y,z coordinates and the change in the position due to motion or vibration. The flex sensor is another sensor that can be used to measure the bending or the amount of deflection of the gloves. The flex sensor's resistance varies when there is bending in the surface of the object to which the sensor is attached. This can be exploited to find the gesture.

These signals can be recognized by devices and translate into natural language. Each gesture is mapped to a word and then converted into speech or text. Communication at work, study, or to use voice assistants gets simpler. At times, devices or appliances can be handled by gestures. Gadgets can be controlled with hand movement without any human intervention.

A Bluetooth module can be used to transmit the signals data to a target device where the output in the form of text or speech can be given. If it's text, then text-to-speech conversion software can be used to translate the data into audio finally.

Since gloves are lightweight, they can be carried easily even while travelling. This would bridge the communication gap between specially abled people with the traditional world (Fig. 7.4).

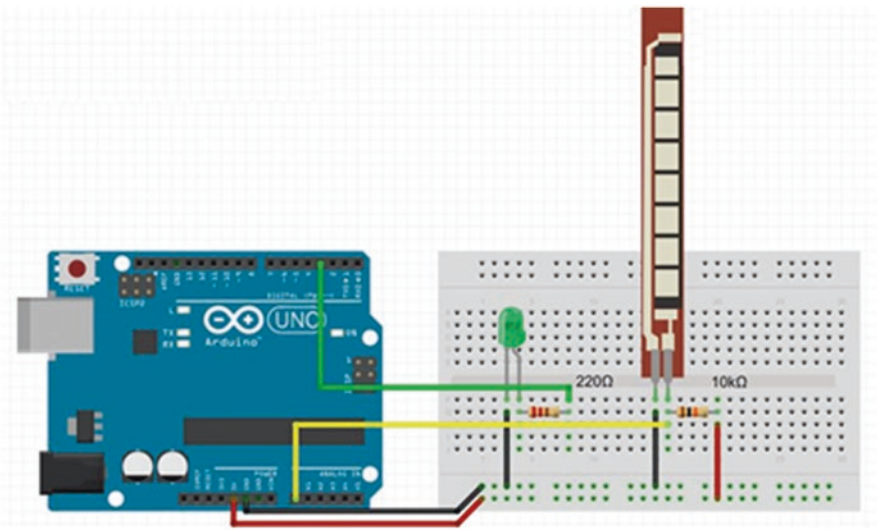


Fig. 7.4 Flex sensor

7.5 Research Challenges

IoT in healthcare is an emerging field of study and hence has challenges [10, 11], few of which we might be known now, and few we might discover in future.

7.5.1 Patient Comfort

IoT devices work with a lot of sensors and devices. Excessive usage of embedded systems make patients uncomfortable. Also, so much hardware makes the system costly but effective. It becomes essential to design comfortable sensors at lesser costs.

7.5.2 Noise Removal

The data collected from sensors are then transmitted to a connected device through WiFi or Bluetooth and then to a monitoring centre if needed. This can affect the quality of the data. Noise removal thus becomes essential. New, better architectures are required to enhance data transmission quality and reduce noise. Researchers need to find out improves techniques for the same.

7.5.3 Data Storage and Analysis

There are massive amounts of data that are to be stored and analysed. Storage of such vast quantities of information and retrieving them is a challenge. We need suitable storage devices that are reliable and large enough to store extensive details. There are millions of people who use the application simultaneously. Every second huge record needs to be updated into the database. For data analytics, the stored documents need to be retrieved. We need faster mediums to access information. The transfer of data requires to be quicker and correct.

7.5.4 Power Consumption

Since the number of sensors and devices connected through a network increases, the amount of power leakage also increases, leading to higher energy consumption. Hardware improvement becomes more crucial. It is relatively more essential to design better optimization algorithms and software that manage hardware efficiently instead of reducing energy usage.

7.5.5 Security

There are a lot of people accessing the data of the devices. Different authentication techniques, therefore, become necessary. For instance, doctors can assess the patient's medical records along with the sensor readings, vaccine or medication information, or any other confidential documents. Since the networks [12] used to connect can be public, they are unstable, and it is possible that there can be a man who can interrupt the connection and get unwanted access. Privacy is paramount, and these devices are very vulnerable to attack.

Hence, there is a need for more good encryption techniques and authentication steps before giving users, be it patients or practitioners access to the data and devices.

When IoT uses the cloud, new issues arise which needs new network architectures that integrate them. The critical concerns during integration are quality of service and quality of experience and data security, privacy and reliability.

7.6 IoT Healthcare Applications: Case Studies

7.6.1 IoT in Diabetes Treatment

A person with high blood sugar levels is said to have diabetes. It is due to improper secretion of insulin by the pancreas. Around 422 million people worldwide, irrespective of their age group, have diabetes, and nearly 1.6 million deaths annually are attributed directly to diabetes. IoT has found its way to help patients suffering from diabetes problem.

Smart Continuous Glucose Monitoring (CGM)

Diabetes patients need to be administered and monitored regularly for treatment. CGM device has been designed to monitor glucose levels in the blood continuously. Readings are taken after regular time intervals. CGM then sends these data to an application [5] over the smartphone or smartwatches where it can be checked easily. This information can be then analysed to detect trends. Health practitioners [13, 14] can also access this information and treat the patient accordingly, irrespective of the geographical location. Family members can also view these data, and the doctor's review regarding the same remotely. The first CGM was approved in 1999. After that, many more like Eversense and Freestyle Libre have come to the market (Fig. 7.5).

Fig. 7.5 Continuous glucose monitoring (CGM)

Insulin Pen

Another device called Insulin Pen has also proved to be helpful for diabetes patients. An insulin pen can record the amount of insulin injected, the dose's time and the type of insulin injected. The smartpen can suggest the patient of the correct type, time and quantity of insulin injection regularly.

An insulin pen is connected to the smartphone application, where all the data are collected in the store. Patients can also make a note of their meals. This information, along with the insulin dose, can be analysed to determine how eating patterns have affected blood sugar levels. The app can also recommend changes in diet patterns. Long-term data can be stored and interpreted this way, reducing the burden of the caretaker. InPen, Gocap and Esysta are some smart insulin pens in the market.

7.6.2 Asthma

Respiratory illnesses like asthma account to significant morbidity amongst people and affect the life quality of millions globally. It is the condition where airways swell and get narrowed, making it difficult to breathe. It is a prevalent chronic, non-communicable disease. It can result in attacks that can be life-threatening.

Smart Inhaler and Bluetooth Spirometer

However, the advent of smart technology has made the scenario better for them by enabling them to monitor their symptoms and make timely treatment possible for them regularly.

Inhalers are drug delivery devices in asthma [15], which enable the patient to inhale the prescribed drug and are chiefly used in respiratory illness like asthma. Spirometry is used to measure the lung functioning, i.e. inhalation and exhalation capacities and lung volumes. This is significant in diagnosing respiratory problems like asthma and chronic obstructive lung diseases wherein the lung functioning might be altered.

Of late, smart inhaler technology has stepped into the markets. These are connected inhalers wherein sensors are attached to inhalers. Spirometers used are also enabled with Bluetooth.

Apps are designed to identify the allergens that can trigger an asthma attack in patients and, thus, issue a prophylactic forecast to the user and prevent an asthmatic attack. Also, these sensors connected to inhalers can monitor the usage of medication in patients. The inhaler reports can be shared with the doctor and check if the correct treatment is being followed or not. Treating doctors can monitor [16] the consistency of medication usage with great ease. Adherence is improved, which in medical terms means that there is more consistency very often. Patients also can use these data to improve their condition by learning how to use the inhaler better.

Propeller Health [17] is one of the biggest producers of smart inhalers. Respimat inhaler and Diskus inhaler are few variants that came into the markets in recent times. These companies collaborate with inhaler and spirometer producing companies and embedded sensors within them. Most sensors work with any inhalers.

Asthma Monitor

Apart from the smart inhalers and Bluetooth spirometers, wearable smart asthma devices are also available. Smart asthma monitors notify the user beforehand of an impending asthmatic attack by either vibration or text message. This device is flexible, small and wearable. So the person wearing it can feel the vibration and get notified before itself. A text message is forwarded to a caretaker or a family member of the patient to draw up a timely action, thus allowing us to manage the episode very early and preventing it from worsening.

The patient can set reminders to maintain regularity of their medications through voice journaling. Also, these smart monitors [18] enable the detection of the inhaler's usage in patients, based on the detected changes. Thus, lots are a boon to asthmatic patients and improve their life quality significantly by helping them set medication reminders. Alert them of an impending asthmatic attack, and also keep a track on their regularity. The app's algorithm is flexible, allowing the device to learn from the changes over time. ADAMM is asthma monitor that has been

introduced in the market for consumers. ADANM means Automated Device for Asthma Monitoring and Management.

7.6.3 Apple in Medical Research

Apple organization have been working on medical research and healthcare. They have designed medical applications to work along with iPhone and Apple smartwatch [19]. Wearable technology with healthcare benefits has marked a begin of new technology.

Parkinson's Disease

Parkinson's disease leads to stiffening of muscles, resulting in difficulty in walking, body coordination and body balance. This is due to damage of brain or nerve cells. Symptoms begin slowly and worsen over time. It becomes crucial to monitor these patients considering their difficulty in movement and talking.

Doctors or physicians usually conduct physical diagnostic tests regularly to monitor the patient's status, symptoms and condition. Each patient has a diary to record the observations overtime to get a broader idea of symptoms. Researchers at Apple have worked to automate this process. They have designed an app and connected iPhone and Apple smartwatches. The data collected are plotted as a graph, and symptoms fluctuations are monitored every minute. Hourly and daily breakdown analysis reports are generated.

These data are also used for research analysis of different health conditions. A detailed study of the data collected from sensors would help gain an insight into the onset and duration of a specific symptom of seizures if any. In medical terms, it is called epilepsy where the body experiences sudden signal disturbances, leading to unconsciousness and convulsions due to abnormal activity in the brain neuron cells. These epilepsies can be recurrent and sudden episodes. Therefore, it becomes even more crucial to study the information.

Depression

Depression is a mental state where one feels loneliness, stress and grief. Patients often tend to remain silent on their condition. But they must speak out. Therapy sessions are necessary to tackle the symptoms. If worsened, depression can, at times, trigger suicidal thoughts.

Apple smartwatch and applications help in monitoring depression. They have designed an app to assess patients with depressive disorders. Participants used the app to monitor their cognition and mood. Cognition refers to the method of gaining knowledge. Stimulus received is processed by our brain to make a judgement and

Fig. 7.6 Apple applications

gain an understanding of events around us. They can be due to conscious or unconscious choices made by our mind.

Daily assessment is done by doing in-depth analysis and cognition tests to derive outcomes. And the results produced are considered to be reliable and robust to a large extent. The collected data have been put to research where the effects of the depression were studied in real time. Like other IoT healthcare devices, Apple apps also share patient information with doctors or professionals to understand the condition.

The app tries to understand the behaviour or pattern in their behaviour, to suggest the person techniques make him feel better. The interactions and conversations with the app help the person understand about emotional well-being (Fig. 7.6).

Fitness and Physical Well-being

Fitness is vital for the muscles and bones in our body. We must give our body regular exercise and physical training sessions. This would improve breathing, the functioning of the heart and lungs. It is necessary to maintain good weight to prevent heart diseases, obesity and a few types of cancers.

There is an application created for the following purpose. GPS is enabled to track the movement of the person. The number of steps taken is recorded along with the distance covered. There are sensors like accelerometer (discussed in earlier Sect. 7.6.3) which is used to estimate the number of calories burned that day. This app is connected with apple smartwatch to track the heartbeat.

The app also analyses sleeping habits by checking phone usage hours and application activities. The app also suggests workout ideas or fitness goals, making it very interactive.

7.6.4 Cancer Treatment

Radiotherapy has emerged as one of the reliable treatment modalities for cancers, mostly around the head and neck region. Despite radiotherapy having the potential to cure most cancers, it comes with its side effects such as extreme dehydration. Radiotherapy is usually given in sessions, i.e. on an outpatient basis. Thus, IoT can play a role here in reducing the symptoms caused both due to cancer and the side effects of radiotherapy. Since most of the time patients are away, they need constant monitoring to address these side effects.

Here, remote sensor technology collects the data from the patient and transmitting it to the treating doctor frequently. Remote sensor technology enables the doctor to have a constant eye on their patients. The doctor can also reschedule the therapies if needed. Bluetooth enabled devices can record any significant fluctuations in parameters like weight or blood pressure of patients and transmit them to the physician.

The patients answer daily questionnaires, and these are assessed by the treating physician who thereby takes a call on the requirement for any intervention in them. Thus, this system can enable the users undergoing radiation therapy for cancer to minimize their side effects and help the treating radiation oncologist to keep a better watch on their patients and their outcomes to the treatment. Overall, IoT is playing a crucial role in improving patients' quality of life by undergoing radiation therapy and improving modality's efficacy. Cyberinfrastructure for Comparative Effectiveness Research (CYCORE) is a platform currently in the market for cancer treatment.

7.6.5 IoT in Pharma Industry

In the pharmaceutical industry, the development of medicines needs to be secure and properly monitored. Safety needs to be maintained when it comes to the distribution of drugs or medicines. If the company fails to meet any other these, it could prove fatal to the patient and lead to a revenue loss if the drugs synthesized have to be discarded.

Therefore, the Pharma industry needs to address these issues and have reasonable control over the facilities and production activities. The company, which would address these concerns, is likely to survive today's competitive markets. Proper shipment of the medicines and in the stipulated time without any delays is very much essential. Few of these operations are outside the facilities and need to be relooked. The industry's quality and quantity standards need to be higher so that they can reach a larger group of patients in case of emergencies.

IoT has helped these companies to meet the demands in the current day market and improve their connectivity. With the introduction of IoT, everyone involved is connected. People are connected with equipment at lesser costs, making it very economical. The supply chains can be closely monitored. Safety of the structure is ensured in addition to making movements faster.

Pharma industries [20] benefit at three levels: manufacturing, maintenance and delivery. IoT sensors help to determine the apt conditions for working in drug synthesis environment. They handle the weight of chemicals and biomaterials so that the equipment can work properly. This would reduce instances of fraud and danger. Trackers help track the drugs to ensure they reach the supply chain during the demanding hours.

One major drawback in manufacturing the drugs is in equipment. There are many reasons for an asset's failure, such as mechanical damage, excessive voltage, chemical deterioration, unstable environment and a lack of maintenance. Pharmaceutical companies cannot risk unplanned equipment breakdown and supply. If this happens, they will have to discard all the materials. It is hence vital to have a sound monitoring system round the clock throughout the day.

IoT serves this purpose. It helps in tracking the status of the machinery and other facilities continuously. It keeps updating this information on components like sterilizers, vacuum pumps, pressure gauges, heat exchangers, pH probes and multi-media filters air compressors.

This information is used to repair the equipment, assess critical issues and maintain the machinery's regular maintenance. In current times, if a component fails, it would take a considerable amount of time to detect the mishap and then even more time to repair it. This will result in certain facilities' unavailability for a long duration which is referred to as downtime. IoT ensures downtime reduction and maintains safety in the working environment.

Such innovative methods will help in proper planning, ensuring maximum resource utilization with the data collected. If IoT is combined with AI, then the pharma companies can predict the conditions and optimize performance. This would lay the foundation of a perfect modernized system.

Controlling the manufacturing conditions with IoT will make the production activities more transparent. Along with manufacturing, the storage environment needs to be given special attention. Atmospheric indicators such as humidity, radiation, temperature, levels of carbon dioxide and light are to be maintained. This is achieved with several sensors.

There is a screen on which this information is updated continuously. The supervisor or the employee in the lab can keep observing these values and in case of

emergencies or odd behaviour take immediate measures. Smart systems can be introduced, predicting this change of conditions and automatically adjusting the parameters to bring back the system to normal conditions. In case there is a disaster, for instance, like machine damage, which can result in leakage of toxic chemicals, the concerned staff member can be alerted. This would help in timely disaster management.

Dutch startup and AntTail developed tiny sensors, which are currently in the market. These sensors are kept in the box while packing the drugs, which help in tracking the packets until their delivery to the consumers. This would help in monitoring the medicines [21] to check if they are delivered correctly and within time (Fig. 7.7).

This tracking is essential unexpected difficulties like vehicle accidents or sudden failure of temperature maintaining units, resulting in fluctuations. Such sudden hard times can have an effect on the customer as well as the pharma company. Therefore, even after production, it becomes more critical to track the supply chain and the delivery route details. If the company becomes aware of the situation, they can ensure specific measures to handle the situation. IoT helps in ensuring that immediate actions are taken to prevent delays or dangers.

Other than sensors, drugs can be packed and marked with batches, tags or smart labels, which can help in identification of the packages. Each batch or QR is unique and helps distinctly track individual delivery until they reach the final destination. Apart from drugs, the vehicles transporting the packages are enabled with GPS to know the geographical location periodically. This will make the shipment process more transparent. The more the number of trackers, the more precise the tracking is as they would serve in case the other breaks down.

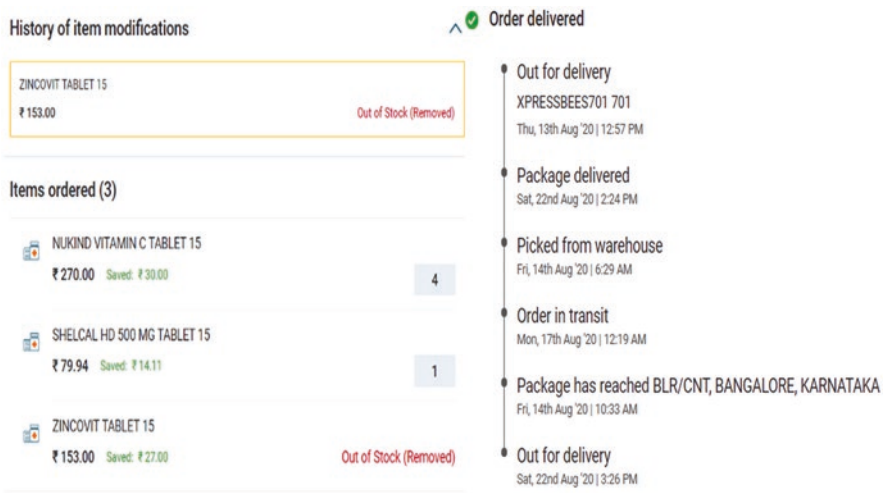


Fig. 7.7 A sample medicine tracking system

The sensors that handle environmental conditions such as temperature, pressure and humidity can alert the driver or the person carrying it, in case of deviation from standards while travelling. The current conditions are compared with the required ones. In case of discrepancy, with such intimidation, timely measures can be taken. If the drugs storage does not meet the storage criteria, they will have to be disposed of. Since all the information has been collected, this can be analysed to predict the frequent mishaps or facilities to be improved. Problems in the delivery route can be worked on to prevent future delays, making the process smoother. Such a report on how the drug was stored will help the caretaker or physician to contribute more to the patient treatment.

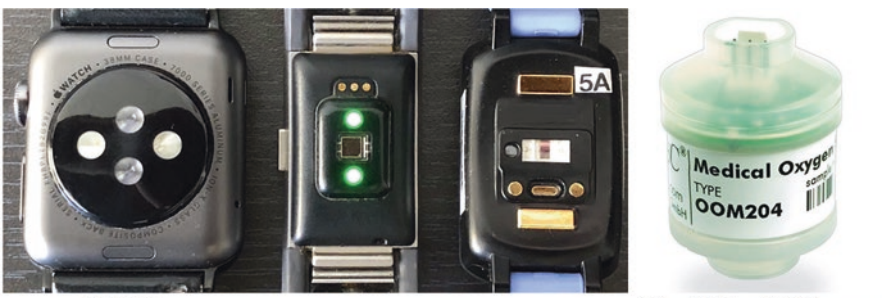
7.7 Commonly Used Sensors

7.7.1 Heartbeat

Smartwatches like those of Apple (refer Sect. 7.6.3.3) use a technology called PPG, i.e. photoplethysmography, for measuring heartbeat [22]. Blood absorbs green colour and reflects red colour giving it a red colour. This technology checks the amount of red and green light visible when it looks at the wrist through the skin. The more amount of green light absorption implies a higher heartbeat rate. A similar idea is used in hospitals where pulse measuring devices are connected to tips of fingers (Fig. 7.8).

7.7.2 Ventilator Oxygen Sensor

The oxygen sensor is to monitor the oxygen gas quantity and concentration of oxygen the patient is receiving through the ventilator. It automatically keeps checking at regular intervals. These sensors are made up of electrogalvanic or



PPG Sensor Ventilator O2 Sensor

Fig. 7.8 PPG sensor ventilator O_2 sensor

electrochemical sensors. They work based on the difference in voltage which varies with difference in oxygen levels.

7.7.3 Temperature Sensors

Temperature sensors measure the surroundings' temperature and convert it into electrical signals that can be recorded and monitored. There are two types of temperatures: contact temperature and non-contact temperature. Contact temperature sensors measure the temperature of the surface they are in contact. Non-contact sensors work by measuring the IR radiations emitted by the object.

7.7.4 Blood Glucose Sensors

Our human body synthesizes enzymes which are proteins. Blood glucose sensors have enzyme-coated strips that react with the blood sample. This meter then calculates the amount of glucose in the blood and sends the output to the monitor. These strips are usually not reusable.

7.8 Conclusion

IoT in healthcare has a bright future. It has a lot of deliverable aim to revolution automation healthcare services. Healthcare facilities across the globe have adopted IoT systems. From top-level hospitals to regular clinics, all are utilizing the real advantages of IoT in healthcare. Upcoming future of IoT in healthcare with being changed with the new IoT innovations will organize business patterns and automate the data monitoring system. IoT can also make healthcare cost-benefit and medically efficient in the future. Many reports say that IoT healthcare will have more customized systems, patient-oriented equipment and doctor-oriented equipment in the next couple of years. With the use of IoT technology, treatment and as well as monitoring will be more precise and proper order. Usually, IoT will also enable patients to access data and personalized care and reduce visits to the hospital.

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