Applications of Internet Of Things (IoT) in Pharmacy

A Project Report Submitted

In Partial Fulfilment of the Requirements

for the Degree of

BACHELOR OF PHARMACY

by

Rabiya Ali
(Enrollment no. 18021020043)

Under the Supervision of

Dr. Shaweta Sharma
Professor
Galgotias University
Greater Noida.

GALGOTIAS
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Department of Pharmacy
GALGOTIAS UNIVERSITY
Greater Noida

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List of abbrevations

API	Application Programming Interface
BAN	Body Area Network
CIM	City Information Model
ERP	Enterprise Resource Planning
GMP	Good Manufacturing Practice
GPRS	General Pocket Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HCI	Human Computer Interaction
IoT	Internet of Things
IoHT	Internet of Health Things
IP	Internet Protocol
NFC	Near Field Communication
OEE	Overall Equipment Effectiveness
PAN	Personal Area Network
pH	Power of Hydrogen
PMI	Physical Mobile Interaction
QbD	Quality by Design
QoS	Quality of Service
RFID	Radio Frequency Identification
TCP	Transmission control Protocol
WSN	Wireless Sensor Network

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CERTIFICATE

This is to certify that project work entitled **"Internet Of Things in Pharmacy"** done by Ms Rabiya Ali submitted to the Department of Pharmacy, is a bonafide research work under the supervision and guidance of Dr Shweta Sharma**,** Professor, Department of Pharmacy, School of Medical and Allied Sciences, Greater Noida. The work is completed and ready for evaluation in partial fulfillment for the award of Bachelor of Pharmacy during the academic year 2021-2022. The project report has not formed the basis for the award of any Degree/Diploma/Fellowship or other similar title to any candidate of any University.

Date:

Prof. Pramod Kumar Sharma
Dean
School of Medical and Allied Sciences
Galgotias University
Greater Noida (U.P.)

<u>BONAFIDE CERTIFICATE</u>

This to certify that the project work entitled **"Internet Of Things in Pharmacy"** is the bonafide research work done by Ms. Rabiya Ali, who carried out the research work under my supervision and guidance for the award of Bachelor of Pharmacy under Galgotias University, Greater Noida during the academic year 2021-2022. To the best of my knowledge the work reported herein is not submitted for award of any other degree or diploma of any other Institute or University.

Dr. Shaweta Sharma
Guide
Professor
School of Medical and Allied Sciences
Galgotias University
Greater Noida (U.P.)

DECLARATION

I hereby declare that the work embodied in this project report entitled **"Internet Of Things in Pharmacy"** in Partial fulfillment of the requirements for the award of Bachelor of Pharmacy, is a record of original and independent research work done by me during the academic year 2021-22 under the supervision and guidance of Dr. Shaweta Sharma, Professor, Department of Pharmacy, School of Medical and Allied Sciences, Galgotias University, Greater Noida. I have not submitted this project for award of any other degree or diploma of any other Institute or University.

Date: Ms. Rabiya Ali

Place: **Name and Signature of candidate**

Acknowledgement

I would like to extend my sincere thanks to Dr Pramod Kumar Sharma, Dean, SMAS for equipping us with all possible resources and continuous motivation during my research work. It was a constant backup for us to produce quality work and contribute to the field of research.

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Rabiya Ali

Abstract

The Internet of Things (IoT) is a network of interconnected computer systems that may communicate data using Unique Identifiers (UIDs). The internet of things (IoT) is a network of smart items that are linked together via the internet because they are equipped with sensors that can receive signals and subsequently exchange information, data, and resources. It reacts to conditions and changes in the environment by reacting and responding. It is quickly becoming one of the most significant parts of future technology, since it provides several benefits in our daily lives. This discusses many aspects of the Internet of Things, including challenges, enabling technologies, features, and applications in several sectors, including transportation, smart cities, health care, culture and tourism, pharma, agriculture, environment, logistics, futuristics and many more. It primarily discusses the advantages of IoT in the healthcare sector, the pharmaceutical value chain, drug production, drug discovery, clinical research, warehousing, and supply chain management. Iot is quite beneficial in terms of saving time, effort, errors and improve quality and increase efficiency. Smart healthcare system has reduced doctor visits and hospital costs. Through telehealth care it can monitor remote patients and deliver healthcare services over a long distance. The wearable devices have sensors that can measure and collect vital signs such as heart rate, blood pressure skin and body temperature, pulse rate, respiration rate, oxygen level and so on. Almost all pharmaceutical firms and contract research organizations are using Iot to get innovative medications and biologics to market in less time and also save money. The use of IoT in pharmaceutical manufacturing is increasing day by day to increase production efficiency and product development. The equipment and machines are connected to internet for better result, accuracy and reduce the production cost. IoT would be utilised in many more fields in the future.

1. Introduction

Kelvin Ashton originated the phrase "internet of things" in 1999 [1]. The Internet of Things (IoT) has achieved widespread recognition and appeal as a result of the fast rise of smart gadgets and high-speed networks. The Internet of Things (IoT) refers to items that are integrated with specific types of electronics, software, or hardware that are connected to the internet. These gadgets are commonly referred to as smart devices since they include sensors and can interact [2, 3].

In the realm of technology, the Internet of Things is a revolutionary paradigm. The Internet of Things (IoT) is made up of two words: "Internet" and "Things." The Internet refers to a global network of interconnected computer systems that use the standard Internet protocol suite (Transmission Control Protocol/Internet Protocol) to connect millions of people all over the world. It's a huge network that connects millions of public, private, commercial, educational, and government networks locally and worldwide using a mix of wireless, digital, and optical networking technologies.

In the Internet of Things, somebody with a heart implant, a farm animal with a biochip transponder, or a car with built-in sensors may be referred to as a 'Thing.' 'Things' in the Internet of Things might include RFID (Radio Frequency Identification) tags, sensors, actuators, mobile phones, and other devices that, thanks to an unusual addressing system, are capable of interacting with one another and complying with the environment to achieve collective goals. [4]

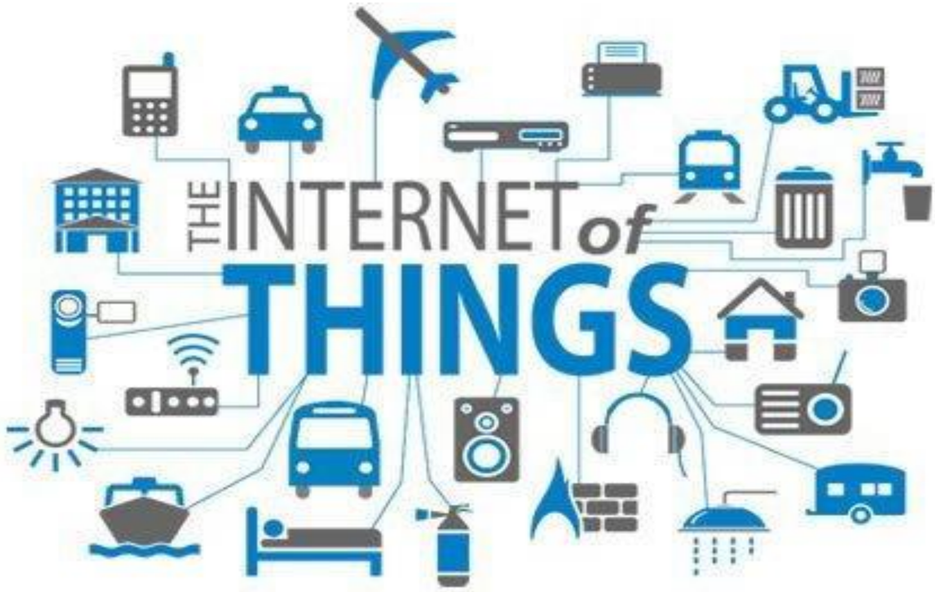

Figure 1- Internet of Things (IoT)

The Internet of Things (IoT) is quickly becoming one of the most crucial parts of future technology, attracting significant interest from a variety of businesses. When linked devices can interact with one another and integrate with vendor-managed inventory systems, customer support systems, business intelligence tools, and business analytics, the actual potential of the IoT for businesses may be completely realised [5].

The Internet of Things could be best described as: "An open and detailed network of smart objects that can self-organize, share information, data and resources, react and respond in reaction to situations and changes in the environment [6].

The Internet of Things (IoT) has transformed conventional living into a high-tech lifestyle in recent years. Smart cities, smart homes, high-tech universities, smart industries, energy conservation, agriculture, hospitals, smart health care centres, and smart transportation are examples of IoT changes [7-10].

IoT scenarios are applied to smart device apps that people utilise in their regular activities in a variety of domains. IoT applications also provide certain advantages for users in terms of decision-making, management, and monitoring of environmental cloud resources [11].

The US National Intelligence Council has identified IoT as one of six "Disruptive Civil Technologies" that could have an impact on US national power [12]. The term "Internet of Things" refers to a "global network of networked items that are uniquely addressable and communicate via standard communication protocols" [13].

2. Challenges to IoT:

1. Data Management Challenge: IoT devices used for a variety of applications create a large volume of data that must be properly stored, managed, and analyzed.

2. Data Mining Challenge: Data generated by IoT devices might be discrete or streaming data from digital sensors. Data mining technologies are becoming increasingly important as more data becomes available for processing and analysis. For screening/understanding, the data required, computer and mathematical models might be used.

3. Privacy Issues: IoT devices may collect a lot of data about their users' whereabouts, which might raise serious privacy problems. Privacy protection is sometimes unproductive for service providers.

4. Security Challenge: Despite the fact that IoT-based technologies have enhanced industrial efficiency and people's general quality of life, there is still a security challenge. With the increased usage of IoT, however, security concerns about attacks by hackers and other cyber criminals should be taken seriously.

5. The Chaos Challenge: IoT-based systems must solve challenges such as privacy, inadequate, complicated communications, and gadgets that have not been thoroughly tested. IoT technologies, if not carefully planned and regulated, have the potential to throw our lives into disarray [14].

3. ENABLING TECHNOLOGIES FOR IoT

The Internet of Items (IoT) is a global infrastructure information society that enables sophisticated linking (physical and virtual) things using interoperable information and communication technologies that are constantly changing. The Internet of Things allows us to communicate with everything around us via the Internet. The Internet of Things encompasses a lot more than machine-to-machine communication, wireless sensor networks, sensor networks 2G/3G/4G GSM GPRS, RFID, WI-FI, GPS, microcontrollers, and processors, among other things. These are the "enabling technologies" that allow "Internet of Things" applications to be developed. There are three types of enabling technologies for the Internet of Things: [15]

(1) technologies that allow "things" to acquire contextual data,

(2) technologies that allow "things" to acquire contextual data, and

(3) technologies that increase security and privacy.

The first two categories may be thought of as functional building blocks for embedding "intelligence" into "things," which are the characteristics that set the IoT apart from the Internet. The third category is not a functional need, but rather a de facto one, without which IoT penetration would be severely limited. [16]

The convergence of numerous supporting technologies allows the IoT idea to be realized in the real world. [17]

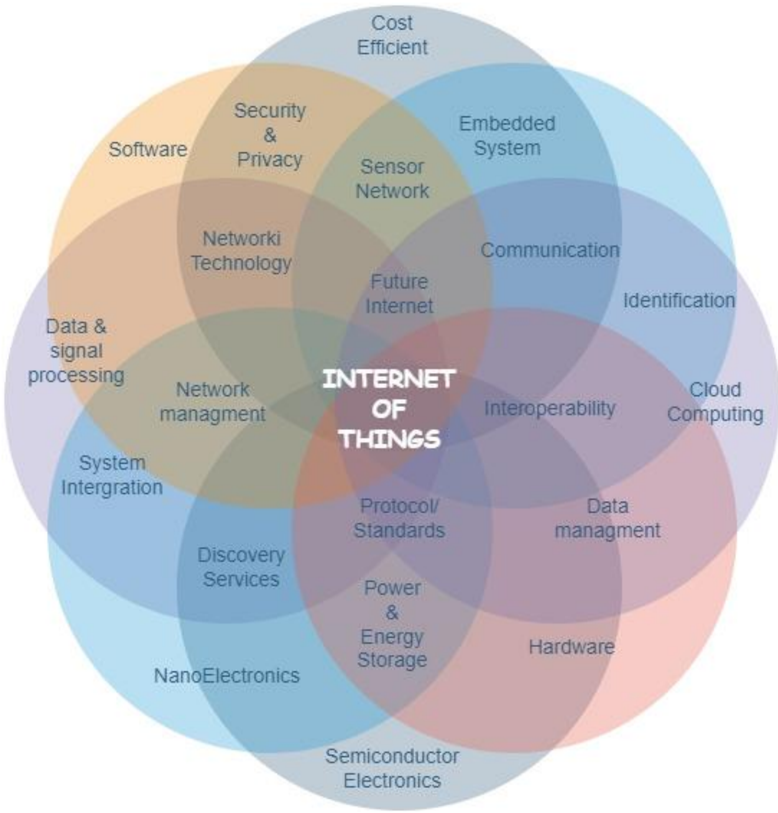

Figure 2- Internet of things: Enabling technology.

4. CHARACTERISTICS OF IoT:

The fundamental characteristics of the IoT are as follows-

Interconnectivity: With regard to the IoT, anything can be interconnected with the global information and communication infrastructure.

Things-related services: The IoT is capable of providing thing-related services within the constraints of things, such as privacy protection and semantic consistency between physical things and their associated virtual things. In order to provide thing-related services within the constraints of things, both the technologies in physical world and information world will change.

Heterogeneity: The devices in the IoT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.

Dynamic changes: The state of devices change dynamically, e.g., sleeping and waking up, connected and/or disconnected as well as the context of devices including location and speed.

Enormous scale: The number of devices that need to be managed and that communicate with each other will be at least an order of magnitude larger than the devices connected to the current Internet.

Safety: As we gain benefits from the IoT, we must not forget about safety. As both the creators and recipients of the IoT, we must design for safety. This includes the safety of our personal data and the safety of our physical well – being. Securing the endpoints, the networks, and the data moving across all of it means creating a security paradigm that will scale.

Connectivity: Connectivity enables network access compatibility. Accessibility is getting on a network while compatibility provides the common ability to consume and produce data. [18-22]

5. Applications of IoT in various fields

In the IoT context, IoT applications use cloud service computing to provide correct composite services by composing existing atomic services for service-based applications [23, 24]. IoT scenarios are applied to smart device apps that people utilize in their regular activities in a variety of domains. IoT applications also provide certain advantages for users in terms of decision-making, management, and monitoring of environmental cloud resources [25]. Regardless of the motives of the many application domains, they all share a common goal: providing smart services to improve the quality of human life [26,27].

The main concern of IoT applications is satisfying Quality of Service (QoS) metrics. User's requirements should be supported by smart services in IoT applications that cover the QoS metrics such as security, cost, service time, energy consumption, reliability and availability. [28,29]

Potential applications of the IoT are numerous and diverse, permeating into practically all areas of every-day life of individuals, enterprises, and society as a whole. The IoT application covers "smart" environments/spaces in domains such as: Transportation, Building, City, Lifestyle, Retail, Agriculture, Factory, Supply chain, Emergency, Healthcare, User interaction, Culture and tourism, Environment and Energy. [30]

The IoT's capabilities enable the development of a vast array of applications, of which only a tiny portion is now available to our society. New applications would certainly improve the quality of our lives in a variety of domains and locations, including at home, when travelling, when sick, at work, while running, and at the gym, to name a few. These settings presently contain things with only rudimentary intelligence and, in many cases, no communication capabilities. Giving these objects the ability to speak with one another and expound on information gathered from their surroundings necessitates the creation of several contexts in which a diverse set of applications may be implemented.

The following domains can be categorised into:

- Transportation and logistics domain.
- The healthcare industry.
- Smart environment domain (home, office, factory).

• The personal and societal spheres.

We may distinguish between those that are immediately relevant or closer to our existing life habits and those that are futuristic, which we can only fantasize about for the time being since the technologies and/or our society are not ready for their implementation (see Fig. 3). We review the short-medium-term applications for each of these categories, as well as a variety of futuristic applications, in the subsections that follow.

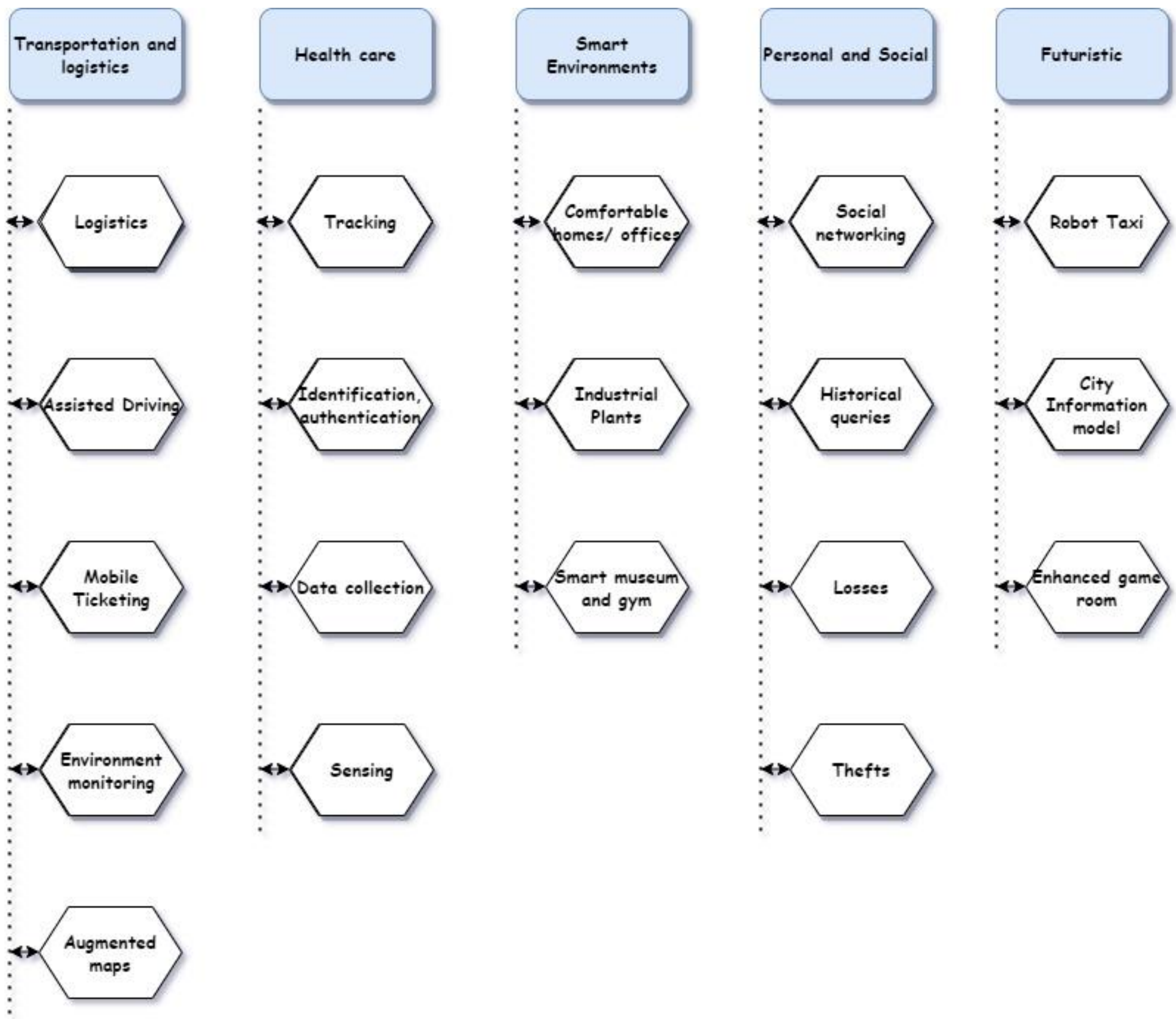

Figure 3 – Different applications of IoT

5.1. Transportation and logistics domain

Advanced cars, trains, buses as well as bicycles along with roads and/or rails are becoming more instrumented with sensors, actuators, and processing power. Roads themselves and transported goods are also equipped with and sensors that send important information to traffic control sites and transportation vehicles to better route the traffic, help in the management of the depots, provide the tourist with appropriate transportation information, and monitor the status of the transported goods. Below, the main applications in the transportation and logistics domain are described.

5.1.1. Logistics

Real-time information processing technology based on RFID and NFC can enable real-time monitoring of nearly every link in the supply chain, including commodity design, raw material procurement, production, transportation, storage, distribution, and sale of semi-products and finished goods, returns processing, and after-sales service. It is also feasible to get product-related information in a rapid, accurate, and timely manner, allowing businesses or even the whole supply chain to adapt quickly to complex and changing markets. As a consequence of the application, typical organizations' reaction time from client demand to commodity supply is 120 days, but sophisticated companies that apply these technologies (such as Wal-Mart and Metro) just need a few days and Real can effectively function with zero safety stock. [31,32]

5.1.2. Assisted driving

Cars, trains, and buses, as well as roads and tracks outfitted with sensors, actuators, and computing power, may offer critical information to a car's driver and/or passengers to aid navigation and safety. Collision avoidance systems and hazardous material transportation monitoring are two examples of typical functions. For planning purposes, government agencies would also benefit from more precise information regarding road traffic patterns. Whereas, with accurate information about traffic jams and incidents, private transportation traffic might better pick the best way. Businesses, such as freight firms, would be able to do more effective route optimization, allowing them to save energy. Information on the movement of goods-transporting vehicles, as well as information about the nature and state of the products, may be combined to offer critical information about delivery time, delays, and defects. This information may also be linked with warehouse status in order to automate the magazine refilling process.

5.1.3. Mobile ticketing

An NFC tag, a visual marking, and a numeric identity can be added to posters or panels that provide information (description, pricing, and schedules) concerning transportation services. By either holding his mobile phone over the NFC tag or pointing his mobile phone to the visual markers, the user may acquire information about numerous kinds of alternatives from the web. The mobile phone obtains information from the linked online services (stations, passenger numbers, prices, available seats, and service types) and allows the user to purchase tickets [33].

5.1.4. Monitoring environmental parameters

Fruits, fresh-cut veggies, meat, and dairy products are perishable foods that are essential to our diet. Thousands of kilometers, if not more, must be travelled from the point of production to the point of consumption, and the conservation status (temperature, humidity, shock) must be monitored throughout to eliminate ambiguity in quality levels for distribution decisions. Pervasive computing and sensor technologies have a lot of potential for increasing food supply chain efficiency. [34,35]

5.1.5. Augmented maps

Touristic maps can include tags that enable NFC-enabled phones to explore them and automatically summon online services that provide information about hotels, restaurants, landmarks, and events in the user's region of interest [36]. There are a variety of Physical Mobile Interaction (PMI) approaches that may be used to supplement the map's information: - hovering within read range of a tag to show extra information about the marker on the phone screen; -

single selection/de-selection of tags by pressing a particular key while the tag is hovered; - single selection/de-selection of tags by pressing a specific key while the tag is hovered; -

multiple tag selection and de-selection: -

choosing tags in a polygon that delimits an area of interest to draw a polygon;-

picking-and-dropping, allowing chosen markers 'picked up' with the phone to be dropped in the itinerary of interest; -

context menu displayed when a marker is hovered [37].

5.2. Healthcare domain

Healthcare is a necessary component of everyday living. Some disorders need round-the-clock monitoring. Diabetes and various cardiac disorders are two examples [38]. The goals of smart healthcare are to make people's lives easier, to keep patients more aware of their status 24 hours a day, to keep them health-aware [39], to improve quality and user experience at a low cost, and to allow patients and regular people to monitor their health without having to go to the hospital [40].

The healthcare business was one of the first to embrace and benefit from the Internet of Things [41]. The benefits of IoT technologies to the healthcare area are many, and the resultant applications are typically divided into four categories: monitoring of things and people (staff and patients), identification and authentication of individuals, automatic data gathering, and sensing [42].

5.2.1. Tracking

Tracking is a feature that allows you to identify a moving person or item. This involves both real-time position tracking, such as patient flow monitoring in hospitals to optimize productivity, and mobility tracking across choke points, such as entry to specified areas. When it comes to assets, the most common uses of tracking are continuous inventory location tracking (for example, for maintenance, availability when needed, and monitoring of usage) and materials tracking to avoid left-ins during surgery, such as specimen and blood products.

5.2.2. Identification and authentication

It includes patient identification to reduce incidents that are harmful to patients (such as the use of the wrong drug, dose, time, or procedure), comprehensive and current electronic medical record maintenance (both in- and out-patient settings), and infant identification in hospitals to avoid mismatching. Identification and authentication are most commonly used in the context of staff to grant access and to improve employee morale by addressing patient safety concerns. Identification and authentication are commonly employed in the context of assets to fulfil the criteria of security processes and to prevent thefts or losses of valuable equipment and items.

5.2.3. Data collection

The main goals of automatic data collection and transmission are to speed up form processing, automate processes (including data entry and collecting mistakes), automate care and procedure audits, and manage medical inventories. This role also has to do with integrating RFID technology with other health information and clinical application technologies within a facility, as well as possible network expansions across providers and locations.

5.2.4. Sensing

Sensor devices provide for patient-centered functions, such as assessing patient problems and delivering real-time data on patient health indicators. Different telemedicine solutions, monitoring patient compliance with drug regiment prescriptions, and alerting for patient well-being are examples of application fields. Sensors can be used in both in-patient and out-patient settings in this capacity. Remote patient monitoring systems based on heterogeneous wireless access may be implemented to reach the patient anywhere, using different wireless technologies to allow continuous bio-signal monitoring in the context of patient mobility [43].

5.3. Smart environments domain

A smart environment, whether it's an office, a house, an industrial plant, or a leisure setting, is one that makes its "work" easy and enjoyable owing to the intelligence of confined things.

5.3.1. Comfortable homes and offices

Sensors and actuators installed in homes and offices can improve our lives in a variety of ways: rooms can be heated according to our preferences and the weather; room lighting can change according to the time of day; domestic incidents can be avoided with proper monitoring and alarm systems; and energy can be saved by automatically turning off electrical equipment when not in use. For example, consider energy providers who use dynamically changing energy prices to influence overall energy consumption in such a way that load peaks are smoothed. An automation logic may reduce power consumption costs throughout the day by observing when prices, which are provided by an external web service and are set based on current energy production and consumption, are low, and by taking into account the specific requirements of each home appliance (battery charger, refrigerator, ovens) [44].

5.3.2. Industrial plants

With a large deployment of RFID tags connected with manufacturing items, smart surroundings can also aid improve automation in industrial operations. In a typical situation, the RFID reader reads the tag when manufacturing items arrive at the processing station. The reader creates an event with all of the essential information, such as the RFID number, and stores it on the network. This event notifies the machine/robot (since it has subscribed to the service) and it picks up the manufacturing portion. It understands how to process the part further by matching data from the business system with the RFID tag. Parallel to this, a wireless sensor put on the machine detects vibration, and if it exceeds a certain threshold, an event is triggered to halt the operation immediately (quality control). When an emergency event is broadcast, devices that ingest it respond appropriately. When the robot gets the emergency shutdown event, it promptly comes to a halt. The plant manager may also examine the status of ERP orders, production progress, device status, and a global picture of all the aspects, as well as the potential side effects of a production line delay owing to shop-floor device faults [45].

5.3.3. Smart museum and gym

The museum and the gym are two examples of smart leisure venues where IoT technology may assist in maximizing the utilization of their resources. Exhibits in the museum, for example, may suggest diverse historical periods (Egyptian period or ice age) with drastically disparate climatic conditions. The structure adapts to these conditions on a local level while also taking into consideration the outside environment. The personal trainer may put each trainee's workout profile into the training machine at the gym, and the system will identify them instantly thanks to the RFID tag. The trainee's health parameters are monitored during the training session, and the recorded results are compared to evaluate if he or she is overtraining or overly relaxed while performing the activities.

5.4. Personal and social domain

This domain contains apps that allow the user to engage with other individuals in order to maintain and create social ties. Indeed, events may automatically send messages to friends to let them know what we are doing or have done in the past, such as moving from/to our house/office, travelling, catching up with old pals, or playing soccer [46].

The principal applications are listed below.

5.4.1. Social networking

This program is about automatically updating information about our social activity on social networking web portals like Twitter and Plaza. RFIDs, for example, may produce events about individuals and locations in real time to provide users with real-time updates in their social networks, which are then collated and published to social networking websites. Users may control their friend lists as well as which events are disclosed to which friends using the application user interfaces, which present a stream of events that their friends have preliminarily set.

5.4.2. Historical queries

Users may investigate patterns in their activity over time by running historical queries on objects and events data. This is particularly important for apps that enable long-term activity like corporate initiatives and partnerships. It is possible to create a digital diary application that captures and shows occurrences in a Google Calendar for later review. Users may then go back over their diaries to see how and with whom they spent their time. The Google Charts API may also be used to create historical trends plots that show where, how, and with whom or what they spent their time over a certain time period.

5.4.3. Losses

A search engine for things is a tool that aids in the recovery of items that we have forgotten where we put them. The most basic web-based RFID application is a search engine for things, which allows users to examine the last recorded position of their tagged objects or search for the location of a specific object. This application's proactive extension uses user-defined events to inform users when the last recorded object position meets certain criteria.

5.4.4. Thefts

An application similar to the previous one might alert the user if certain things are moved from a restricted area (the owner's home or workplace), indicating that they are being stolen. In this instance, the owner and/or security personnel must be alerted as soon as possible. For example, when stolen items leave the premises without permission, the application may send an SMS to the users (such as a laptop, a wallet or an ornament).

5.5. Futuristic applications domain

The applications discussed in the preceding sections are feasible since they have either been deployed or may be implemented in a short/medium time frame because the necessary technologies are currently accessible. Apart from these, we may imagine a plethora of additional applications, which we refer to as futuristic since they rely on technology (communications, sensing, materials, and/or industrial processes) that are either yet to be developed or whose implementation is too difficult. In terms of necessary research and possible effect, these applications are much more intriguing. The SENSEIFP7 Project [47] provides an interesting overview of these types of applications, from which we have selected the three most intriguing.

5.5.1. Robot taxi

In future cities, robot taxis swarm together, moving in flocks, providing service where it is needed in a timely and efficient manner. The robot taxis respond to real-time traffic movements of the city, and are calibrated to reduce congestion at bottlenecks in the city and to service pick-up areas that are most frequently used. With or without a human driver, they weave in and out of traffic at optimum speeds, avoiding accidents through proximity sensors, which repel them magnetically from other objects on the road. They can be hailed from the side of the street by pointing a mobile phone at them or by using hand gestures. The user’s location is automatically tracked via GPS and enables users to request a taxi to be at a certain location at a particular time by just pointing it out on a detailed map. On the rare occasions they are not in use, the taxis head for ‘pit-stops’ where they automatically stack themselves into tight bays which are instrumented with sensors where actuators set off recharging batteries, perform simple maintenance tasks and clean the cars. The pit-stops communicate with each other to ensure no over or underutilization [47].

5.5.2. City information model

The concept behind a City Information Model (CIM) is that the status and performance of each building and urban fabric – such as pedestrian walkways, cycle paths, and heavier infrastructure like sewers, rail lines, and bus corridors – are continuously monitored by the city government and made available to third parties via a series of APIs, even if some information is confidential. As a result, nothing can be lawfully constructed unless it is compliant with CIM. Facilities management services connect with one another and with the CIM in order to share energy in the most cost-effective and resource-efficient way possible. They automatically trade excess energy with one another, with prices set to meet supply and demand. Planning and design, in this view, is a continuous social process in which the performance of each item is reported in real time and compared to others. Movement patterns, environmental performance, and overall product and meeting the challenges may all be extrapolated from population fluctuations.

5.5.3. Enhanced game room

Location, movement, acceleration, humidity, temperature, noise, speech, visual information, heart rate, and blood pressure are all sensed by the improved gaming room as well as the players. This information is used by the room to monitor enthusiasm and energy levels in order to manage game activities based on the player's state. Various objects are also strewn about the area, and the goal is to crawl and jump from one to the next without hitting the ground. Long leaps and tough to reach locations get points. On the wall-mounted screen, the game also displays a target. Whoever is the first to attain that goal wins. The game maintains track of the players' achievements as they work their way around the room. RFID tags on items in the room are recognized their controller. They must contact the thing with it in order to score. The system steadily increases the difficulty of the game as it proceeds. Initially, the things they must reach are close by and simple to reach. It becomes too tough at some point, and both players must touch the ground with their feet. The game then emits a loud noise to signify that something isn't right. The area has now detected that one player is somewhat taller and faster than the other, and it has begun to move the things closer to him so that he can keep up. The game then adjusts the difficulty level and target based on the players' successes in order to maintain a high level of excitement as measured by the console's sensing devices.

6. IoT implementation in Health Care department

A person's most basic requirement is healthcare. In terms of therapy and money, physicians, on the other hand, are not always honest with their patients. Another flaw in the healthcare system is the scarcity of medical facilities capable of tracing a patient's medical history and providing appropriate therapy. As a result, the healthcare system must be optimised to improve its efficiency [48].

IoT technology is also helping to improve the healthcare monitoring system in order to give better emergency assistance to patients [49]. Smartphones have become an indispensable part of people's daily lives, and they are now connected to sensors that track their health [50].

Individual resource management is aided by the Internet of Things (IoT) healthcare system, which enables for effective monitoring and tracking [51]. Cloud computing is used to handle healthcare data and offers resource sharing benefits such as flexibility, data service integration with scalable data storage, parallel processing, and early security issue detection [52].

IoT revolution is restyling contemporary health care with promising technological, economic, and social prospects [53]. Health sensing components have developed much squeezed and portable, allowing patients to wear them round the clock for monitoring. If these monitoring devices are fortified with inimitable identifiers like RFID, then those devices can be exclusively identified over the Internet. It deeds as an information retriever, retrieving information from the physical world to the digital world. An IoT aided health monitoring device connected to a patient can be considered as a virtual patient in the ordinal world. The simulated patient has the exact physiological conditions as the real patient. A doctor can observe a patient only a uncommon times a day but critical health issues can occur at any moment, 24/7 monitoring of health facts is crucial and it is necessary. As IoT assisted patients can be accessed over the Internet and by other machines, the health state of a patient can be supervised uninterruptedly, allowing critical illness to be detected at the right time so that applicable actions can be taken.

Also, IoT can support to collect health records. Generating statistical information correlated to health condition, can be performed by machines. It is faster and voluminous and error free assortment of data that is conceivable manual methods could never achieve. Generating statistics, surveillance, risk drawing of diseases can be completed using remote health data [54].

It is a network of real physical nodes that are connected to each other over the internet to collect and exchange data. This connection can be wired or wireless, and it also includes one or more sensors that are either attached to the physical nodes or placed in specific locations [55]. These sensors may collect and store data from various types of nodes, execute a series of actions depending on the data, and then deliver the results to the relevant stakeholders [56].

Biomedical sensors detect, collect, and store various types of body signs; the collected data is managed by a software programme developed for the user terminal, such as smartwatches; the terminal is connected to a gateway via short-span protocols, such as Bluetooth, Ipv6 over Low Power Wireless Personal Area Networks; and the terminal is coupled to a gateway via short-span protocols, such as Bluetooth, Ipv6 over Low Power Wireless Personal Area Networks (6LoWPAN). The gateway is connected to a server or cloud for data processing and eventual storage [56,57]. Figure 4 depicts a health-care facility that uses IoT and cloud technologies to enable remote patient monitoring. Data is collected using smart sensors.

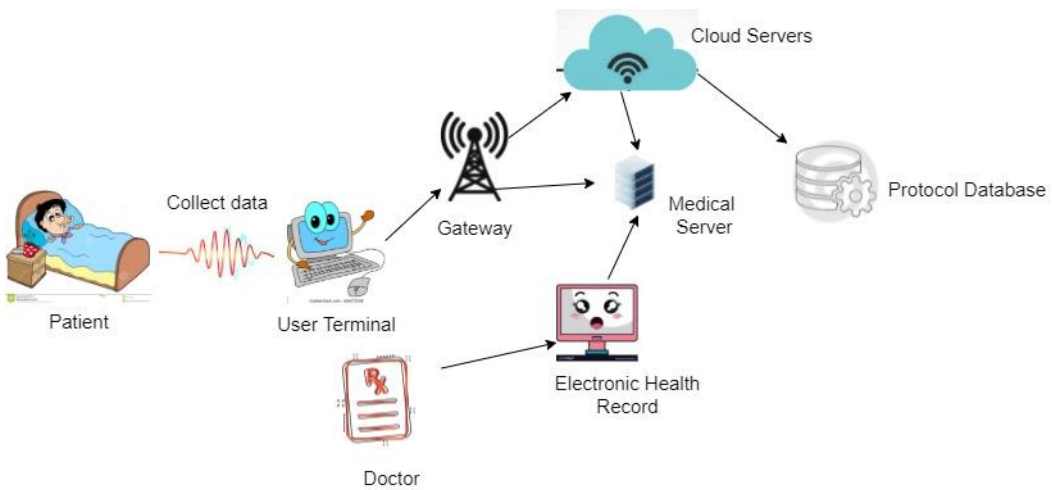

Figure 4 - Illustration of IoHT architecture

Smart healthcare has various advantages, including shorter doctor visits, lower hospital costs, and improved service quality. The IoHT services are designed to meet the demands of society. However, several drawbacks emerge, such as a security risk owing to the enormous volume of sensitive data being shared, the possibility of being disconnected from healthcare services when the patient leaves the cellular region, and the devices running out of energy [56,58,57].

There are two types of wireless networks: BAN and PAN. BAN covers the entire human body, using sensors on the skin or incorporated in clothing, whereas PAN only covers a few metres. They are the most widely utilised e-healthcare networks. Figure 5 depicts the Bluetooth and Ad-hoc networks protocols that are utilised in both BAN and PAN. Ad-hoc networks are infrastructure-less networks built on the fly (i.e., does not rely on pre-existing infrastructure), and they are on-demand networks [59]. Bluetooth is a short-range, low-power wireless radio technology.

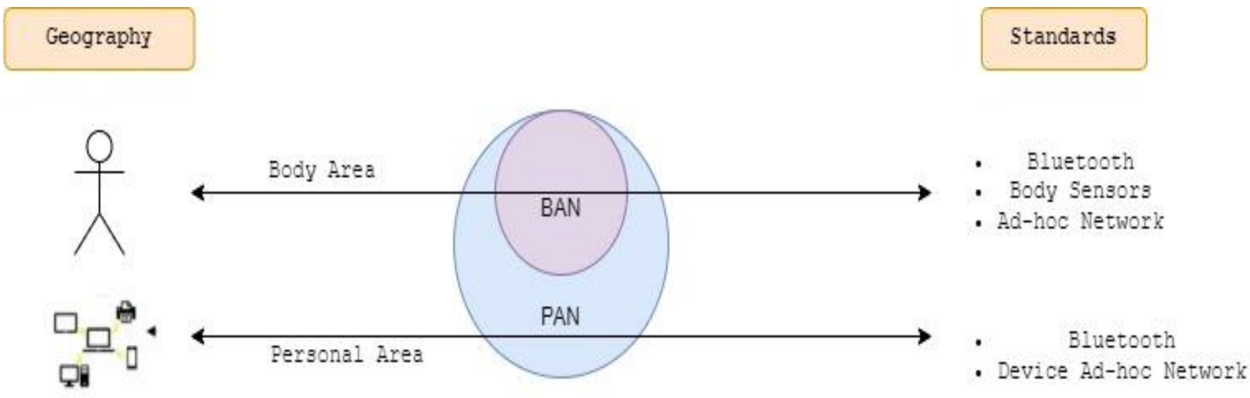

Figure 5- Wireless technologies.

6.1 Internet of Health Thing (IoHT) is classified into three categories:

1. m-Health
2. Wearable devices
3. Telehealth-care

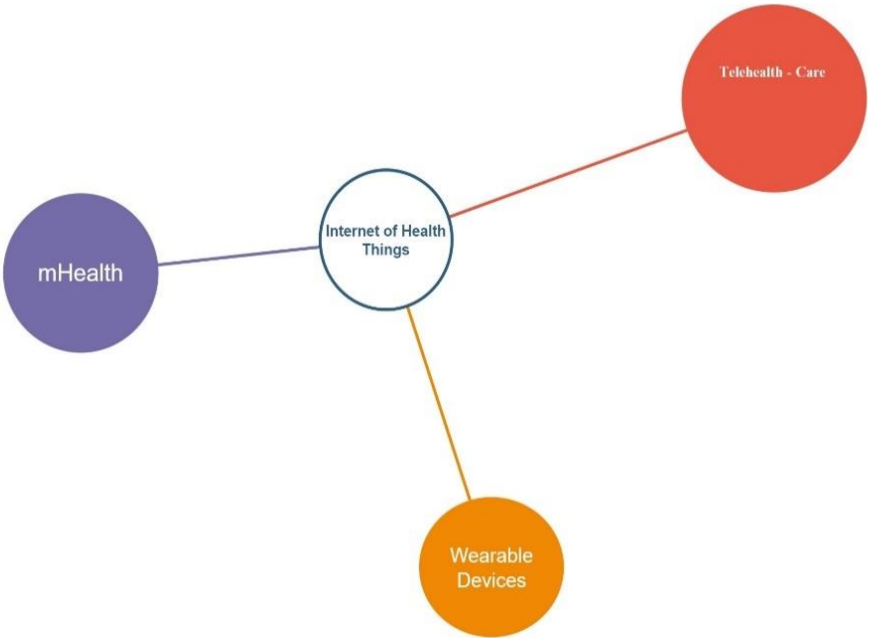

Figure 6- It represent categories of IoHT

6.1.1 M-health

Because of the increasing expansion, popularity, availability, and performance of smartphones and tablets, a new sector of the smart health care business called Mobile health (m-Health) [60] has emerged, which supports medical and public health using smartphone applications to enhance healthcare outcomes. It was created to make it easier to govern and monitor people's health and fitness [61]. The integration of mobile communication and network technology into the healthcare system is what it's called. [62]

Figure 7- Smartphone applications for healthcare.

6.1.2 Wearable device

Wearable sensors are employed in a variety of industries, including internment, security, and medicine [63]. The use of biosensors in the medical area has resulted in an astounding improvement in the quality of life for both the elderly and the young.

The wearable systems in healthcare monitoring employ a body area network, which is made up of numerous biosensors that can measure and gather vital signs in the user's body, such as heart rate, blood pressure, body and skin temperature, oxygen saturation, respiration rate, EKG, and so on. The collected data is sent to a central node through a wireless or cable connection [64]. Figure 8 depicts a few instances of wearable technology.

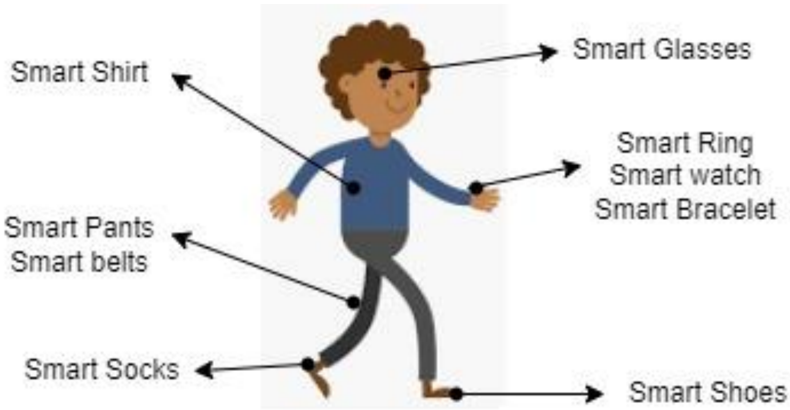

Figure 8- Wearable devices

6.1.3 Telehealth-care

Telehealth was created to allow remote patient monitoring and to deliver healthcare services over a long distance. The distance between the patient and the healthcare professional is bridged. One of the most significant advantages of telehealth is that it reduces the expense of typical medical appointments. Telecommunications, computers, and mobile technologies are used to provide health care services remotely, allowing patients and providers to consult across geographical boundaries. It might be technology that users or clinicians utilise to remotely improve or assist health care services. Figure 9 shows several sensors used in telehealth care, including heart rate, breathing, an electroencephalography (EEG) sensor for recording brain electrical activity, an insulin pump, blood pressure, body temperature, and pulse oximetry. The collected data is then sent to the Personal Digital Assistant (PDA), where it flows as shown in Figure 4.

These little wireless sensors are ideal for users since they are portable and readily concealable, ensuring user privacy

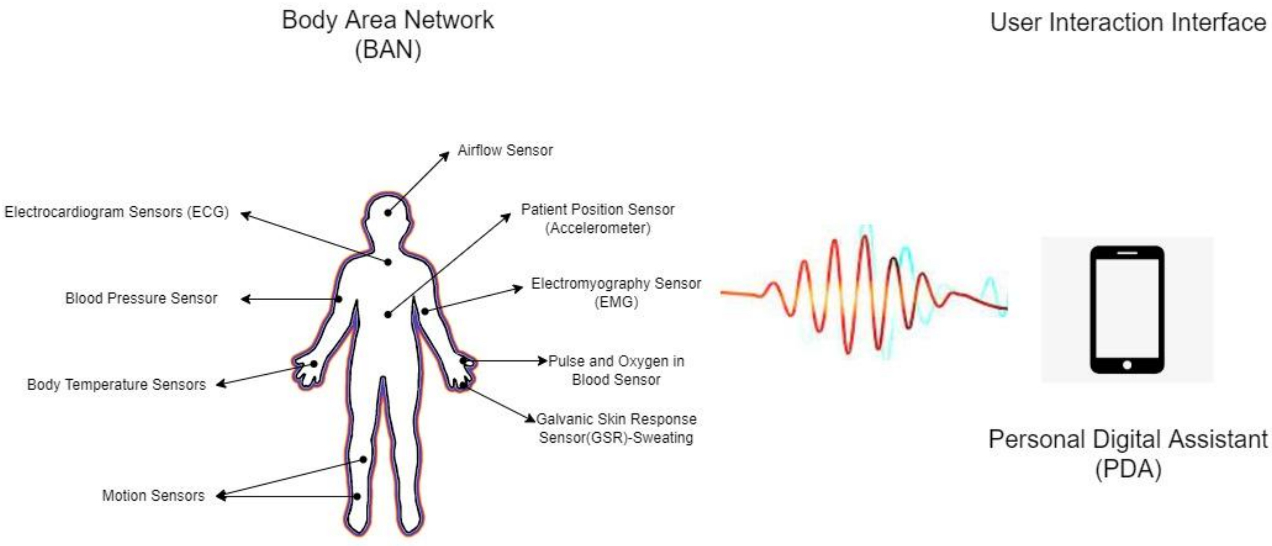

Figure 9- General overview of sensors in Tele-health care.

THE DIFFERENCE BETWEEN M-HEALTH, WEARABLE, TELEHEALTH

Table 1. Comparison between M-Health, Wearable, Telehealth

Features	**m-Health**	**Wearable**	**Telehealth**
Scope	Fitness,Sports, Wellbeing	Vital Signs	All the health cases (Broader)
Interaction	Self- management	Patient-to-doctor Patient-to-patient	Patient-to-doctor Patient-to-patient
Network Type	Wireless communication	Wireless communication (BAN)	Wireless communication (PAN, BAN)
Technology	Mobile /Application	Biosensors	Sensors
Remote Monitoring	No	Yes	Yes

Telehealth uses a variety of technologies to treat all types of health issues and difficulties; m-health and wearable gadgets do not handle all types of health issues. m-health developed as a result of the growing use of mobile phones, which now account for 3.5 billion [65] of the world's population.

6.2 Challenges of IoT in Health Care

Traditional applications and IoT applications (e.g., native or web-based applications) are significantly different in many ways. It will convey enormous opportunities and even bigger challenges such as:

• Processing enormous volumes of data published at a high rapidity needs a matching infrastructure.

• Meaningful, Effective, and cost-effective mining and analysis of the input events prerequisite a robust analytics platform.

• Because the number of connected devices is likely to grow dramatically, the architecture required for scalable applications must be able to integrate with a wide range of devices and systems.

• In order to read all of the raw data created by millions of connected devices, high network bandwidth is required.

Why There are no universal standards for data collected by devices, which might lead to data being generated and inhibit widespread use.

• There might be security problems since linked devices are vulnerable to hacking, necessitating the implementation of secure uniqueness management and authentication.

• With the large volume of data generated by devices, defining data archival, purging, and retention might be a difficult process. [66]

6.3 OBJECTIVE OF IoT IN HEALTHCARE

- Wearable IoT devices have been a great hit in the market due to the availability of Internet for a reasonable price and the convenience of access to Internet. The development of ambient intelligence is critical since end users, clients, and consumers in the healthcare network are people (patients or health-conscious persons).
- To give Ambient intelligence for continuous learning about the data of patients, every needed action caused by a recognized event is executed. Integration of autonomous control and human computer interface (HCI) technologies into ambient intelligence might help IoT-assisted healthcare services improve even further.
- To obtain real-time information about humans using an IoT wearable device.
- Preprocessing of human data (if necessary). Analyzing and Prediction of chronic illnesses in the early stages using data mining techniques, which gives a framework for decision-making.
- To provide IoT-based healthcare solutions at any time and in any location. [67]

7. Application of IoT in Pharmaceutical Value Chain

Although IoT adoption in the pharmaceutical sector is still in its early stages, smart devices and machine-to-machine communication technologies are frequently employed to digitize processes and data. IoT is driving innovation in the severely regulated pharmaceutical business by challenging old traditional paradigms from medication development to distribution. Pharmaceutical companies are now much more open to experimenting with IoT technology in order to improve quality, increase efficiency, reduce production mistakes, and raise stakeholder expectations for medicine effectiveness.

The application of IoT in pharmaceutical production, supply chain, clinical research, and patient interaction not only helps to reduce time to market for medications, but it also helps to discover faults across the value chain via real-time data flow to enhance quality. IoT in manufacturing and supply chain management is a popular investment area for a variety of businesses. Connected equipment, materials, men, smart packaging, cold chain monitoring, and sample lifecycle management are some of the conventional IoT applications that are particularly well suited for many pharmaceutical companies.

The majority of pharmaceutical production processes are done in batches, and most of the equipment is self-contained. Because of a lack of information on the condition of the equipment, executives are unable to make informed decisions to improve overall equipment effectiveness (OEE) in areas such as batch scheduling and maintenance, despite the presence of well-established industrial automation and control technologies. IoT technology enable businesses to link and increase their visibility into shop floor operations, allowing them to improve production and ensure GMP compliance (Fig. 10) [68].

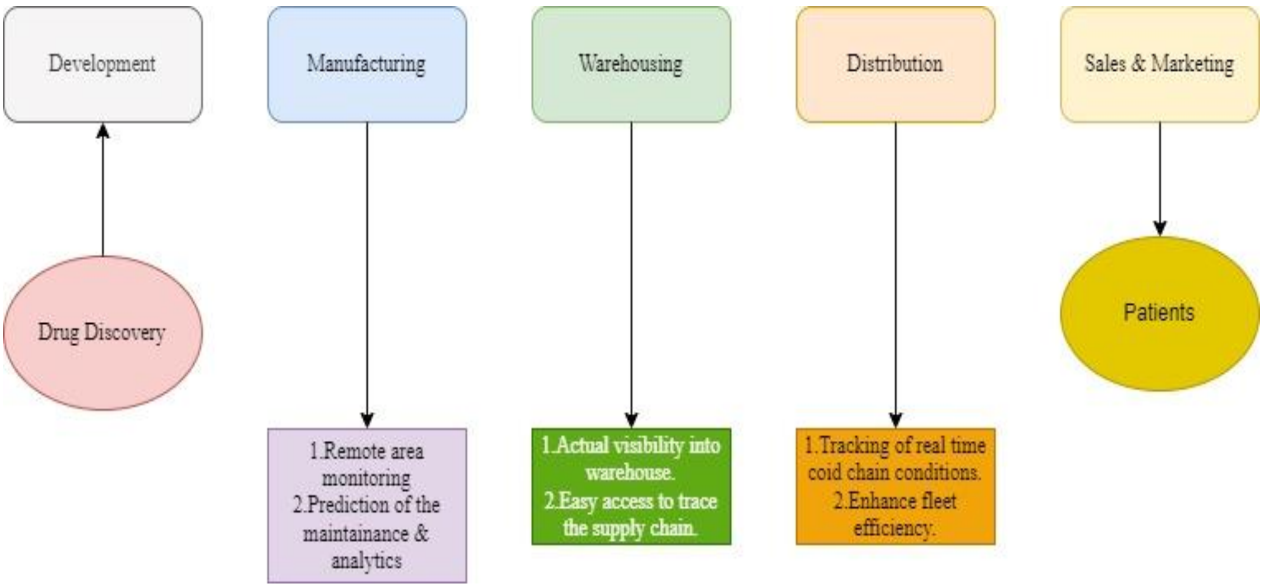

Figure 10- IoT application in different pharmaceutical processes across the value chain.

8. IoT in Pharmaceutical Manufacturing

The Internet of Things for Pharmaceutical Manufacturing, or IoT-PM, has the potential to totally change the way pharmaceutical facilities operate. It provides for real-time monitoring of industrial operations from any location. Waste can be decreased, equipment utilisation may be raised, and production costs can be lowered as a consequence of real-time monitoring. The Industrial Internet of Things (IoT) is described as the interconnection of processes, goods, and people, with the industrial sector reaping the biggest benefits.

Although equipment may already be connected, the Internet of Things (IoT) gives an additional benefit by utilising data and processing power. [69]. This gives you a lot of information on how the plant works, as well as a way to track and manage equipment performance before it breaks down.

The Internet of Things is leading the pharmaceutical manufacturing business toward a paperless, human-less environment [70]. Implementing the Internet of Things would lead to a significant shift toward outcome-based personalised pharmaceuticals produced using personalised manufacturing processes. Wherever practical, IoT technology has been included into the manufacturing processes of 30 percent of the top 20 pharmaceutical companies. To survive and grow in this competitive business, chemical and pharmaceutical companies must use IoT-PM to increase product development and production efficiency.

Equipment and machines are getting more digitalized as a result of their capacity to connect over the internet [71]. IoT in pharmaceutical manufacturing has the ability to reduce production costs, provide real-time monitoring and control, optimize pharmaceutical unit operations, and enhance patient outcomes [72]. IoT-based factory control systems include supervisory control and data acquisition systems, manufacturing execution systems, manufacturing data, and distributed control systems, to name a few. These systems are important for monitoring and managing manufacturing activities so that product quality may be improved.

Pharmaceutical firms use IoT technology in their production facilities to ease regular manufacturing by achieving standardisation, reduced cycle time, and data integrity inside manufacturing plants, hence facilitating the process of continuous manufacturing. This method aids pharmaceutical businesses in reducing production costs and time while also improving product quality. IoT aids in the standardisation of production processes as well as data integrity. In a manufacturing facility, IoT solutions give insight from production through distribution, resulting in increased operational efficiency [73].

8.1 Major Benefits of Internet of Things in pharmaceutical manufacturing are as follows:

• IoT acts as a stimulus for paperless production, requiring fewer manual interventions, as equipment and recipe parameters become more intimately connected and available.

• As the health-care industry moves toward diagnostic-based therapy, IoT-enabled personalized drug manufacture for smaller-scale manufacturing is necessary.

• The Internet of Things (IoT) can collect data from a variety of processes and link sophisticated equipment to provide insight into the process beyond performance and efficiency.

• Connects different plant floor equipment, connects with one another, and shares information across the plant and up to top management levels. These provide an easy way to standardize the procedure.

• Manufacturers benefit from IoT-enabled smarter plants because they can access data in real time to better monitor production and obtain insight from point of production to market reach.

• When an issue arises, manufacturers retrieve the data as needed to monitor and trace the process, which alerts and prompts the recall of the items from the market.

• Quality by Design (QbD) will be efficiently implemented and monitored using IoT to gain a thorough understanding of the process, which will help to improve safety and protect the brand's market value.

• Electronic batch records provide more cost-effective and quicker data interpretation without affecting normal operations.

•IoT-enabled modularization of pharmaceutical manufacturing plants is a must. The Internet of Things enables automation and the scaling up or down of manufacturing in response to market conditions. This allows for faster manufacturing while adhering to regulatory criteria for certain markets and areas.

Both manufacturers and suppliers need a better grasp of IoT in order to make the most of it. IoT is more commonly employed for modest solutions that are required for a specific point in a process, but its full potential has yet to be realized.

Why is it necessary to modularize IoT-enabled pharmaceutical manufacturing plants? Production may be automated and scaled up or down in response to market conditions thanks to the Internet of Things. This allows for faster manufacturing while still adhering to regulatory standards in certain markets and regions.

In the pharmaceutical industry, IoT sensors are progressively being put in numerous departments. These IoT sensors have been effectively employed in pharmaceutical businesses to integrate data across many departments, including production units located across multiple sites. As a result of IoT sensors, businesses can control everything that happens in the manufacturing unit in real time and from afar.

The materials used in the pharmaceutical sector are extremely delicate and must be handled in a controlled atmosphere. IoT sensors and trackers are reported to be utilised in such cases to track and regulate ideal conditions for handling biomaterials and chemicals, as well as ensuring that equipment runs smoothly. Pharmaceutical companies are not interested in shutting down equipment on an ad hoc basis. [74]

The internet of things does this by continually updating the status information of components in various types of equipment, such as:

- Air compressors
- Sterilizers
- Heat exchangers
- Multi-media filters
- Vacuum pumps
- Pressure gauges
- pH probes

The data collected by IoT sensors may be utilized for equipment maintenance and repair, as well as avoiding significant issues, reducing downtime, and assuring workplace safety. This offers you a complete picture of how the equipment is being used. When managing biomaterials, IoT sensors put in the production plant's surroundings are critical. As a result, environmental indicators such as- may be monitored. [75] Networks between robots, humans, and the Internet are established in new situations like CO_2, Temperature, Humidity, Light, and Radiation.

8.2 The major uses of IoT in the manufacturing plant covers the following points.

• **Predictive maintenance**: This term refers to all linked assets in a manufacturing facility. Machine failures can be forecast, and emergency situations can be dealt with quickly. Machine learning may be used to construct algorithms by analyzing data gathered over time. These might help you make quick judgments.

• **Connected Factory**: This phrase refers to a factory network that is connected to the Internet, allowing for comprehensive situation monitoring and administration.

• **Connected Mine**: This mine links all of the mining activities, vehicles, and personal safety devices together.

• **Supply Chain Control**: This part keeps track of the storage conditions and raw material supply chain utilised to feed the machine, as well as product tracking for traceability purposes.

8.3 Fewer applications of IoT in the pharmaceutical manufacturing and supply chains:

• Intelligent serialisation, which automatically recognises items, gathers data, and feeds it into the system.

• Predicting machine and equipment maintenance.

• Medicine tailored to the individual.

• Drugs printed in 3D.

• Capture and report parameters utilising RFID and sensors in real-time logistical visibility.

• Intelligent warehousing and distribution.

Pharmaceutical manufacturing plants have incorporated IoT technology to optimise and increase the efficiency of their machinery and processes. It saves time and eliminates human mistake while also producing a large amount of data that must be analysed for analysis. [76]

9. IoT IN DRUG DISCOVERY

Machine learning and artificial intelligence are already driving the early stages of drug development. Machine learning algorithms are being used by researchers to speed up medication development and create a powerful and long-lasting medicinal pipeline. Machine-learning algorithms have already gained traction in pharmaceutical labs because to the rise of Cloud computing. This article describes the future lab's concept, which is centred on digital connection and focuses on delivering novel pharmaceuticals to the health-care market [77].

IoT, cloud computing, machine learning, and other technologies can help develop new pharmaceuticals faster, cheaper, and more effectively [78].

Various data sets are interconnected during the drug development process to detect the behaviour pattern of the chemical under investigation. It depicts how it behaves in terms of the patient's medical result for the drug under investigation, based on previously saved data. It is estimated that one out of every thousand compounds first confirmed to be safe will be authorised by the FDA [79].

The use of IoT-based data analysis in the drug discovery systems environment improves study repeatability and decreases human participation and error in the process and testing [80]. They use established systems to improve the quality of their products. Researchers working on medication development can use technology to remove drug failures in the early phases of the process, before moving on to the clinical trial stage. They can change the chemical of interest to remedy the concerns, or they can abandon the method and save the data for future research. The process of medication discovery is not simple; it must first pass through a series of rigorous restrictions before reaching the market. Because one out of every ten thousand compounds reach the market, corporations are wary of making large investments in traditional drug development methods [81]. Despite the fact that the Internet of Things has enormous promise in the life sciences, many scientists are still hesitant to employ it in their daily research.

10. IoT IN CLINICAL TRIAL

Clinical trials need intricate designs, as well as the assistance of healthcare professionals. This is part of the ongoing monitoring and communication that occurs during clinical studies. The traditional technique entails the patient making direct contact with healthcare personnel in order to gather data and other clinical outcome markers. The use of IoT lowers these barriers, which is a boon to companies conducting clinical studies. In clinical trials, IoT has the capacity to efficiently and effectively collect data and analyse it in a secure and timely manner. Clinical trial companies can remotely monitor patients by combining medical equipment with IoT networks.

Body temperature, hydration levels, sleep cycles, and other everyday activities are passively and in real time recorded from the individuals. This method of data capture ensures efficient and effective information transfer. This approach of data gathering via IoT allows patients to have a pleasant clinical trial experience while continuing to conduct their regular work. [82]

Almost all pharmaceutical firms, contract research organizations, and service providers intend to boost their usage of IoT in order to get innovative medications and biologics to market in a faster time frame and save money. Using IoT to collect data in unique ways and storing it in the cloud allows researchers to better understand the safety and efficacy of experimental medications in clinical trials. Trials with fewer sites and patient monitoring at home or at a local clinic, where data collected via devices might be uploaded to the cloud and accessible in real time by clinical coordinators. The number of patients, as well as the number of geographic locations in which trials are conducted, can be expanded, resulting in the prospect of bringing novel treatments to market more quickly.

The Internet of Things-based revolution in the Life Sciences sector is still in its early phases. Pharmaceutical and biotechnology companies are in a unique position to accelerate clinical outcomes while spending millions of dollars and reaping the rewards soon. The notion of ingestible tablets with tiny cameras is being tested, which will monitor dose management for chronic illness patients [83].

11. IoT IN WAREHOUSING

The pharmaceutical sector relies heavily on warehousing. To maintain a continuous and timely supply of medicinal items, pharmaceutical companies operate storage/warehousing facilities around the country. Regardless of the nature or character of their commodities, most pharmaceutical businesses prefer to oversee their warehouse operations and storage conditions internally, therefore keeping warehouse operations in-house may be a conscious option. According to a McKinsey study, storage costs account for 95% of pharma logistics costs, making it an expensive business [84]. It's tough to keep track of things in the warehouse and make maximum use of workers and transportation equipment without having real-time insight into the activities. Warehouse tasks like as inventory management, product sorting, and incoming and outgoing shipment become more efficient and accurate when IoT is used.

This improves warehouse service while also improving the efficiency of the operation. Wireless video monitoring systems, WSN technology, and RFID technology may all aid in the general administration and supervision of warehouse activities.

RFID technology efficiently enhances the rate of product identification and conducts monitoring and product control when used in incoming and outbound operations. When RFID-tagged stocks or storage devices pass through an area containing RFID readers, the readers may read the data and send it to the control systems. During inbound and outgoing operations, Zhou et al. [85] employed RFID technology to execute pallet placement to reduce travel distance, labour cost, and picking distance.

The Internet of Things (IoT) helps warehouse operations in the following ways [86]:

1. Inventory Tracking at Every Step: The Internet of Things (IoT) assists in linking pharmaceutical items from the time they arrive at the warehouse until they are delivered to the client. The Internet of Things gives information about the expiration date, allowing action to be performed and thereby reducing product damage-related losses. This will help to reduce product waste and spoilage.

2. Vision Picking (With Smart Glasses): Vision picking is an augmented reality branch that allows operators to work successfully without using their hands. This has the potential to improve store efficiency. The operators can see the order selecting directions on a visual display using smart glasses. Because it is a wearable device, it requires very little training for warehouse operators or personnel, and no structural adjustments are necessary at the warehouse.

3. Data Analytics: As the IoT links, the scheme may monitor all logistics, trends, and possibilities. Furthermore, with real-time visibility, easy and rapid responses to market developments are possible. Areas in the warehouse that are not operating well may be quickly identified using the information provided by the IoT, and strategic decisions can be made.

This has the ability to increase the efficiency of the store. Using smart glasses, the operators can observe the order selecting directions on a visual display. Because it is a wearable gadget, warehouse operators and staff will need very minimal training, and no structural changes will be required at the warehouse because of the IoT connections, the scheme can keep track of all logistics, trends, and opportunities. Furthermore, real-time visibility allows for quick and easy responses to market changes. Using the information supplied by the IoT, areas in the warehouse that are not performing well may be promptly detected, and strategic decisions can be taken.

12. IOT IN SUPPLY CHAIN MANAGEMENT

Despite the fact that the pharmaceutical sector is directly linked to healthcare and medical research, it is also dependent on manufacturing, supply chain, and transportation. Because of the unique environmental conditions that pharmaceutical goods must meet, the pharmaceutical supply chain has a few unique preferences and critical points that are distinct from the standard supply chain network. Manufacturers—Retailer—Hospitals/Pharmacy—Consumer—Manufacturers, Retailers, Hospitals. [87]

With both income prospects and operational efficiency, IoT is poised to alter the supply chain process. Asset tracking, operator interactions, forecasting and inventories, connected fleets, maintenance scheduling, and revenue potential are all part of the operational efficiency [88].

12.1 Objectives in the pharmaceutical supply chain that need to be accomplished are:

1. Raw material suppliers must guarantee that all raw materials and substances provided to pharmaceutical companies are properly identified.

2. Tags must be scanned and inserted into the database during the manufacturing process.

3. Each batch of raw materials is allocated a unique serial number. This comprises information such as the date of manufacturing and expiration, as well as directions for using the medications.

4. The RFID system's software firm reads the tag information and changes it to an electronic pedigree format.

5. As soon as the pharmaceutical product enters the pharmaceutical supply chain, further data is supplied into the electronic pedigree system [89].

With the use of smart pharma packaging, the cargo and medications may be tracked promptly and precisely, enabling a smooth and cost-effective supply chain. When the Internet of Things is used to the packaging process, it provides a number of advantages, including unidirectional transmission, medication monitoring, and a method for showing status. In a sector where counterfeit medications routinely enter the value chain, the usage of IoT in packaging and supply chain is critical.

Tracing the flow of medicine inventories at various stages might boost efficiency and be cost effective [90]. 2-D bar codes, RFID tags, and smart packaging are utilized in pharmaceutical firms to trace each critical step from manufacture through dispensing. As a consequence, a complete digital footprint may be obtained [91].

13. FUTURE TECHNOLOGICAL DEVELOPMENTS FOR IoT.

To allow physical objects to operate in changing contexts and to be linked all of the time, enabling technologies such as semiconductor electronics, communications, sensors, smart phones, embedded systems, cloud networking, network virtualization, and software will be required.

Future development and research requirements for IoT enabling technologies are shown in the table below. [15,16]

TECHNOLOGY	FUTURE DEVELOPMENT	RESEARCH NEEDS
Hardware Devices	•Nanotechnology •Miniaturization of chipsets •Ultra low power circuits	•Low cost modular devices •Ultra low power EPROM/FRAM •Autonomous circuits
SENSOR	•Smart sensors (bio-chemical) •More sensors (tiny sensors) •Low power sensors •Wireless sensor network for sensor connectivity	•Self powering sensors • Intelligence of sensors
Communication Technology	•On chip antennas •Wide spectrum and spectrum aware protocols •Unified protocol over wide Spectrum •Multi-functional reconfigurable chips	•Protocols for interoperability •Multi-protocol chips •Gateway convergence •On chip networks •Longer range (higher frequencies – tenths of GHz) •5G developments
Network Technology	•Self aware and self organizing networks •Self-learning, self-repairing networks •IPv6- enabled scalability •Ubiquitous IPv6-based IoT deployment	•Grid/Cloud network •Software defined networks •Service based network •Need based network
Software and algorithms	•Goal oriented software •Distributed intelligence, problem solving •User oriented software	•Context aware software •Evolving software •Self reusable software •Autonomous things: •Self configurable •Self healing •Self management
Data and Signal Processing Technology	•Context aware data processing and data responses •Cognitive processing and optimization •IoT complex data analysis •IoT intelligent data visualization •Energy, frequency spectrum aware data processing	•Common sensor ontology •Distributed energy efficient data processing •Autonomous computing
Discovery and Search Engine Technologies	•Automatic route tagging and identification management centers •On demand service discovery/integration	•Scalable Discovery services for connecting things with services
Security & Privacy Technologies	•User centric context-aware privacy and privacy policies •Privacy aware data processing •Security and privacy profiles selection based on security and privacy need	•Low cost, secure and high performance identification/ authentication devices •Decentralized approaches to privacy by information localization

Table 2: Future development & research needs

14. CONCLUSION

The internet of things refers to physical items equipped with sensors, software, and other technologies that connect to and share data with other devices and systems over the internet or another communications network. It is becoming the important aspects of future technologies as it has several benefits in our daily life. This paper covers all the factors related to IoT such as challenges, enabling technologies, characteristics and applications of IoT in different sector such as transportations, smart city, health care department, culture and tourism, pharma sector, agriculture, environment and energy and many more. It mainly outlines the benefits of IoT in healthcare department, pharmaceutical value chain, manufacturing of drugs, IoT in drug discovery, clinical research, warehousing and in supply chain management. In upcoming decades there is some scope for the future development of various technologies like hardware devices, sensors, network technologies etc and their respective research needs.

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