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SURVEY

Illuminating Healthcare Management: A Comprehensive Review of IoT-Enabled Chronic Disease Monitoring

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ABSTRACT Present dynamic performance reputation and technical innovations in Internet of Things (IoT) technologies have endowed ultra-inexpensive, energy effcient, smart, and tiny IoT gadgets. IoT gadgets can be easily implanted inside, attached to, or placed around the chronic patient body, and they can be employed in several healthcare monitoring systems such as mobile, wearable, and implantable healthcare monitoring for chronic diseases. Healthcare monitoring for chronic diseases is one of the major applications of IoT and is also a typical challenging area. The rapidly rising proportion of patients with chronic diseases brought enormous pressure on governments and healthcare providers and required up-to-date long-term healthcare service and continuous monitoring. In this survey paper, we extensively review numerous industrial and non-commercial contemporary healthcare monitoring systems (HMS) and applications. We present a design layout of IoT-based HMS for chronic diseases. We presented societal and technological challenges associated with the design of IoT-based HMS and their solutions. To accomplish this, more than 80 different healthcare monitoring systems have been characterized and classied. Moreover, we describe contemporary healthcare monitoring networks and communication technologies. This review also presents the dynamic capabilities of key IoT technologies for chronic diseases healthcare monitoring to show dedicated research pathways to IoT researchers. Last, we deeply analyze different healthcare monitoring systems and describe open issues that will help researchers and healthcare system designers design future systems.

INDEX TERMS Internet of things (IoT), healthcare monitoring systems (HMS), chronic diseases, body sensor network, societal and technological challenges, industrial and non-commercial.

I. INTRODUCTION

Healthcare systems worldwide are currently facing many serious problems [1], [2], such as a rapidly growing ratio of aging citizens, chronic diseases with a large proportion of the elderly afflicted, substantial economic losses due to chronic diseases, and soaring healthcare expenditure. Some literature has dealt with population dynamics in the Americas and China. In India, and Russia [1]. According to the US Census Bureau, the percentage of elderly individuals in the US, China, India, and Russia in 2014 databases were 14.5%, 9.6%, 5.8%, and 13.3%, respectively. Policies suggest that by 2050, there will be a dramatic increase in the aging population, amounting to 20.9%, 26.9%, 14.7%, and 25.7%, accordingly for these countries. This fast-paced growth will demand medicare resources, significantly reducing older adults's standard of living. In addition, the depredation of the environment is responsible for the spurt of chronic diseases among the elderly as shown in figure 1.

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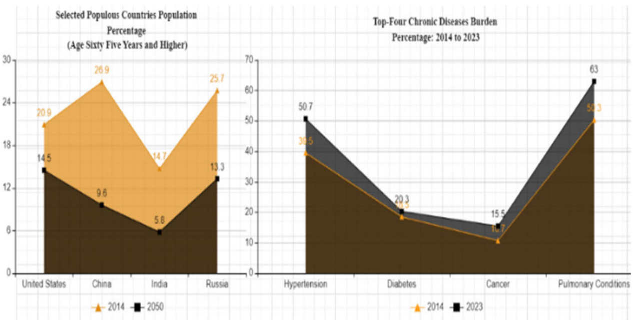

FIGURE 1. Older citizens in populous countries and chronic diseases burden.

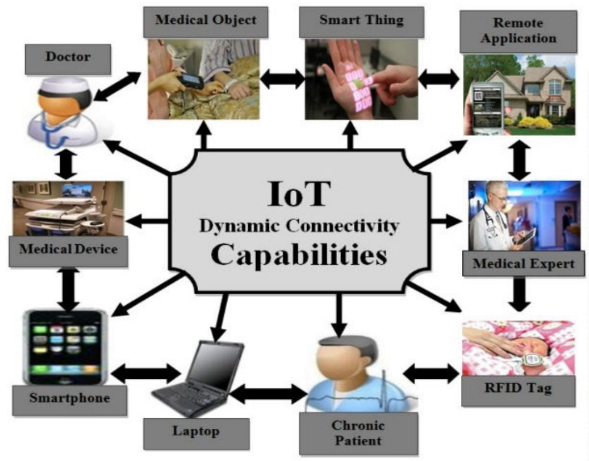

FIGURE 2. IoT connects all the healthcare monitoring actors, gadgets, and medical devices.

Chronic diseases, including diabetes, cardiovascular diseases, cancer, asthma, hypertension, stroke, kidney diseases, pulmonary conditions, and obesity, are not only long-term illnesses but also progress very slowly over a period of time. This is the most important cause of death and disability (63% and 43%, respectively) worldwide [2]. What is more, chronic illnesses are the main factors of difficult healthcare issues at an international scale [1], supported by a lack of healthcare sservices and monitoring. Chronic diseases have a huge economic impact, causing heavy gross domestic losses, with the US at -16.2 billion, China at -13.5 billion, India at -16 billion, and Russia at -16 billion $ [3]. (https://app.ocr.com/ocr) Such problems can prove detrimental to the world economy.

The evolution of the Internet of Things (IoT) offers promising avenues for addressing the challenges of chronic disease management. However, alongside its potential benefits, IoT implementation in healthcare faces critical challenges, particularly concerning data privacy and security. As such, there is a pressing need for a nuanced exploration of how IoT has evolved within the context of chronic disease management, coupled with a critical analysis of key challenges such as data privacy and security. This review aims to fill the research gap by providing a comprehensive examination of IoT applications in chronic disease management. It will encompass various IoT applications and chronic diseases, offering insights into the current landscape, challenges, and future directions. Given the timeliness and relevance of IoT in healthcare, particularly in addressing the growing burden of chronic diseases, this review holds significant importance in shaping the future of healthcare delivery and improving patient outcomes.

Healthcare expenses arrived at an alarming stage [3]; healthcare expenses of the United States were out of control in 2013 because of exceeded \$2.7 trillion, which is expected to be twice (\$4.6 trillion) in 2020 [3]. The healthcare expense per citizen is \$7,681, which is almost 16.2% of GDP of the US. China spends 4.7% of the GDP on healthcare, and it increases 15% yearly [3]. The facts above obviously raise several critical questions:

- How can we manage the intensifying population of older citizens with one or more chronic diseases?
- How can we deliver contemporary healthcare to patients in regions where there is a shortage of healthcare providers?
- How can we raise the independence and contribution of a growing number of older citizens with chronic diseases?

To answer the questions above, we must apply modifications to present healthcare systems. There is a need to use the Internet of Things (IoT) in healthcare systems to heighten the quality of long-term healthcare services with lower monetary and medicinal resources. Monitoring the health of older citizens in their own homes has been widely suggested to respond to the above critical questions. IoT technologies illustrated in figure 2 smartly connect humans, machines, medical devices, and medical systems. IoT ensures an effective healthcare system, healthcare monitoring for chronic diseases, monitoring of medical assets, monitoring of drug intake, and monitoring of medical waste management.

Healthcare monitoring for chronic diseases is boosting significantly. The encouraging factors include a growing percentage of chronic patients requiring continuous monitoring. Offering healthcare for these will be a crucial challenge. For this reason, it is necessary to design and develop IoT-based healthcare monitoring for chronic diseases, which could lessen the work burden on the medical service providers. Conversely, traditional healthcare monitoring systems are inadequate in several ways. These systems mostly rely upon labor-intensive work. They make use of many equipment that are tremendously expensive, substantial, and inconvenient to deploy. This is because electric wiring and cables confine chronic patients' activity and impede their frequent activities. Moreover, they traditionally necessitate the chronic patient to adhere to the spot where the monitoring equipment is used.

For instance, chronic patients should stay in the clinic throughout the monitoring sessions. Subsequently, excessive resources, initiatives, and costs could be misused (e.g., devoted beds, medical personnel, charges to remain in medical facilities, etc.). Additionally, healthcare monitoring is routinely auxiliary and negligible to a certain time period, which simply provides a snap of the wellness condition. Hence, transitory health problems might go undetected. This is one of the reasons that existing healthcare monitoring systems need significant heightening to concentrate on affordable health delivery, prompt illness detection, and avoidance of health monitoring in an inconspicuous situation. Therefore, providing individualized sustainable healthcare facilities to all is a vital challenge for IoT researchers and medical institutions. Considering that IoT systems are taking in all other systems around it, healthcare monitoring for chronic diseases will most likely be a vital system to be taken part of in IoT. From the existing literature of contextual work, there has been a considerable significant improvement in the healthcare monitoring domain and its applications. For example, THCMS, RHCMS, MHCMS, WHCMS, and IPHCMS have excellently enhanced the efficacy of healthcare monitoring for chronic diseases such as diabetes, cardiovascular, stroke, cancer, asthma, falls, Parkinson's, pulmonary conditions, Alzheimer's, and hypertension [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14].

In the earlier surveys [15], [16], [17], [18], [19], [20], [21], [22], [23], we found numerous surveys of healthcare monitoring systems addressing specific HMS features. For instance, the latest survey [24] describes a complete review of congestion control objectives. mechanisms/approaches anticipated for wireless sensor networks. Abro et al. [21] deliver some comprehensive details of LOBIN for health monitoring, in upcoming clinic atmospheres. Jin et al. [15] provide a present improvement and impending direction of study on wearable and implantable BANs for constant monitoring of individuals. An enthusiastic survey by Liu et al. [25], mainly emphasizes the wireless body area networks technologies, applications, and design concerns. Yang et al. [26] present the general idea of WBANs and recent progress concerning the newest standards. Abro et al. [19] provide a survey of modern studies and improvements in wearable biosensor systems for healthcare monitoring. Serhani et al. [20] attempt to broadly review the wearable ECG monitoring systems which are mostly associated with elderly people. Abro et al. [27] describe the IoT application in the field of environmental monitoring and supervision. Moreover, a current survey by Trinh et al. [28] presents the enhancement in DTN congestion control. Authors just design space and apply it to categorize current DTN congestion control mechanisms. Widely surveyed by Salih et al. [29] provide a carrier Ethernet congestion management mechanism. Comprehending the Internet of nano gadgets and techniques, deployed in Internet of Things-based systems are reviewed by Qadri et al. [30].

In this paper,

TABLE 1. Acronyms.

Abbreviation	Description
IoT	Internet of things
HMS	Healthcare monitoring system
RHCMS	Remote healthcare monitoring systems
MHCMS	Mobile healthcare monitoring systems
WHCMS	Wearable healthcare monitoring systems
IPHCMS	Implantable healthcare monitoring systems
HMSFCD	Healthcare monitoring for chronic diseases
CDHCMS	Chronic diseases healthcare monitoring system
BSN	Body sensor network
WLAN	Wireless local area network
WBAN	Wireless body area network
PAN	Personal area network
HAN	Home area network
GSM	Global system for mobile communication
GPRS	General packet radio service
BG	Blood glucose
BT	Body temperature
HR	Heart rate
ECG	Electrocardiogram
EMG	Electromyography
NIBP	Non-invasive blood pressure
Spo2	Blood oxygen saturation
BP	Blood pressure
EEG	Electroencephalography
RFID	Radio frequency identification
NFC	Near field communication
UDM	Universal diagnostic module
RMD	Remote medical device
CT	Communication technologies
GSR	Galvanic skin response
PPG	Photoplethysmogram
WMG	Wrist mounted device
MD	Medical devices
FD	Fluid density
RMD	Remote medical device
BS	Body sensor
AM	Arduino microcontroller
IT	Infrared thermometer
PFCB	Planar-fashionable circuit board
CI	Communication interface
MICS	Medical implant communication service
AMON	Care and alert portable telemedical monitor
MAGIC	Maglietta interattiva computerizzata
HCMSFCD	Healthcare monitoring system for chronic diseases
AALP	Ambient assisted living platforms
MDIS	Medical dispenser infusion pump
DTM	Data transmission module
ADE	Automatic diagnosis engine
JADE	Java agent development environment

- We perform a thorough survey aimed at obtaining the most recent methodologies in heterogeneous healthcare monitoring systems research, which covers areas left by the existing surveys.
- This paper provides a detailed design block diagram of an IoT-driven healthcare monitoring system dedicated for chronic diseases, therein focusing on the essential IoT technolgoies underrepresented in existing surveys.

TABLE 2. Existing healthcare monitoring systems year-wise.

Healthcare Monitoring	The year 2020	Years 2016-2023	Years 2016-2023	Years 2016-2023	The no. of related systems
RHCMS	[33]-[35]	[36]-[38] [45]-[48] [14],[50]	[39]-[40]	[41]-[44]	19
MHCMS	[51]-[53]	[54]-[55] [60]-[62] [48],[66]-[68]	[56]-[57] [63]-[64]	[58]-[59] [65]	19
WHCMS	[69]-[70]	[71]-[72] [79]-[80]	[14]-[15]	[11], [74]-[78] [80]-[82]	18
IPHCMS	[84],[85]	[86]-[88] [91]-[94] ,[97]	[89]	[90]	14
The no. of related systems year-wise	10	33	09	18	70

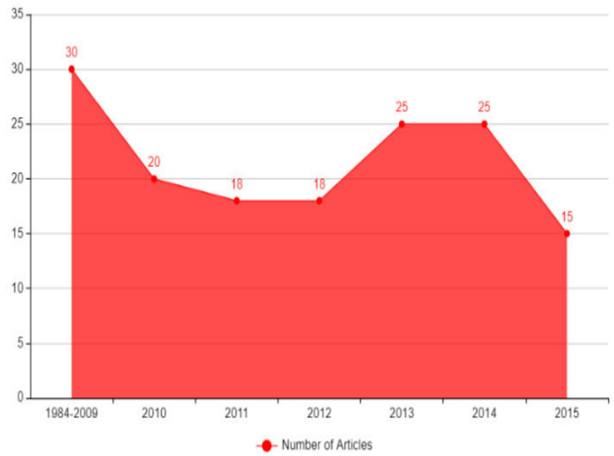

FIGURE 3. Chosen research articles.

- The main intention of this article is to introduce different state-of-the-art health monitoring systems, both in the industry and non-commercial, indicating their drawbacks and come up with improvements.
- In our survey, we categorize healthcare monitoring research into five major areas: THCMS, RHCMS, MHCMS, WHCMS and IPHCMS (Table 1 for abbreviation explanation.)
- Every health monitoring system has its own attributes, as depicted in figure 3, in which the main non-horizontally deployed (i.e., non-cooperative) systems in our area are represented.
- Table 2 and Table 3 collect the most prominent healthcare monitoring systems and their applications developed over the past three decades, we examine them in detail and recommend future development.
- All systems and findings put forth in this study provide useful directions and ideas for researchers undertaking IoT-based healthcare investigations.

The rest of this paper is organized as follows. Section II describes the research and progress in healthcare monitoring systems and applications. Section III explores contemporary healthcare monitoring networks and communication technologies. Section IV presents IoT key technologies for chronic disease healthcare monitoring. Section V discusses open issues. Finally, Section VI concludes the paper.

II. RESEARCH AND PROGRESS IN HEALTHCARE MONITORING DOMAIN

This section describes the state-of-the-art research and innovation in the healthcare monitoring domains such as homes, hospitals, and rustic areas from 1984 to 2015. Moreover, we introduce special-purpose and general-purpose remote healthcare monitoring systems (RHCMS), mobile healthcare monitoring systems (MHCMS), wearable healthcare monitoring systems (WHCMS), implantable healthcare monitoring systems (IPHCMS), and traditional healthcare monitoring systems. Furthermore, we deeply analyze them and suggest further improvement.

Today, IoT will undoubtedly have many applications in the healthcare domain, with the opportunity to use smart gadgets such as tags, mobile phones, and nodes with small sensor capacities to monitor chronic patients' physical conditions [31]. The benefits acquired are in prevention and efficient noting chronic illnesses, medical diagnosis, and offering fast health attention in cases of health complications [32]. Small sensing units that are wearable, implantable, locatable, addressable, and legible, along with smartphones, can potentially maintain patient healthcare records, thereby safeguarding the patient's life during emergencies. In the present literature, many researchers, academicians, and companies are working on personal healthcare, pervasive healthcare, ubiquitous healthcare, and health monitoring systems such as THCMS, RHCMS, MHCMS, WHCMS, and IPHCMS to provide adequate healthcare service for all. IoT was less discussed, and these systems still required some improvements or changes because innovations are taking place rapidly in the healthcare domain due to dramatic changes occurring in smart technologies. Based on the progress over the past years,

TABLE 3. Utilization of healthcare monitoring application.

In Residence/home Environment	In Hospital/clinical Environment	In Extreme/harsh Environments	The no. of related applications
[5], [12], [98] [103]-[104]	[99]-[100]	[101]-[102]	09

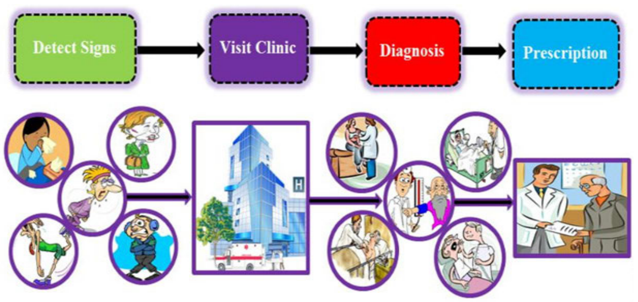

FIGURE 4. Traditional healthcare monitoring system.

we consider the healthcare monitoring systems in this survey that were suggested from 1984 to 2023.

A. TRADITIONAL HEALTHCARE MONITORING SYSTEMS

Traditional healthcare monitoring systems have been often used in the past five decades, and these systems mainly rely on wired-based devices, and medical professionals are required to operate the systems to monitor patients' vital signs as illustrated in figure 4. For example, Holter monitors acquire physiological data for off-line processing. These systems are inadequate, complex, reactive, time-consuming, expensive, and ineffective.

B. REMOTE HEALTHCARE MONITORING SYSTEMS

Remote healthcare monitoring systems [36], [39], [41], [42], [43], [44] provide information to users so that they can analyze far-away patients' health information such as (blood pressure, heart rate, temperature, glucose levels, medication adherence, blood oxygen saturation, and physical activity level) remotely and makes accurate and on-time decisions. A much more in-depth description of picked remote healthcare monitoring systems (RHCMS) is shown in Table 4. Table 4 presents the reference number of systems, title of the system, targeted application, technology/module, health parameters, hardware description, and in the last outcomes/description/ remarks of systems.

1) CRUCIAL INVESTIGATION ANALYSIS AND FURTHER RESEARCH

Remote healthcare monitoring systems can synthesize specific patient health information, perform multiple evaluations, and present the results to a physician, and specialist quickly, anytime and anywhere. These systems can contribute to improving different features of real-time data accessing quality of patient's health information (for instance. completeness and timelines). The remote healthcare monitoring process consists of obtaining, storing, transmitting, analyzing, notifying, and intervening in the health information of remote patients; continuously transmitting medical data may cause loss/delay in real-time data transmission. Remote health monitoring systems still require further research on the effective transmission of real-time data and their reliability, security, and automation.

C. MOBILE HEALTHCARE MONITORING SYSTEMS

Mobile healthcare monitoring systems are the primary type of healthcare monitoring that use Bluetooth, ZigBee, and WIFI, are used to design WLAN, WPAN, and WSN networks and connect to the internet to acquire, store, analyze and transmit the vital signs readings of patient's to the medical database server through mobile using 3G and GPRS [56], [57], [58], [64], [65], [74], [105], [106]. Mobile healthcare monitoring systems not only offer mobility to chronic patients but also permit medical doctors so these medical professionals could access chronic patient's information anytime and anywhere. This carries significant benefits to each patient and healthcare provider. Throughout the procedure of designing a mobile healthcare monitoring system, tiny sensors serve as PDAs that supervise the state of a patient, while additionally benefiting medical professionals through delivering or perhaps acquiring quick SMS, either to hospitals to inquire about the patient's information or to the patient to remind him or her about needed drug or even assessments.

Mobile health monitoring systems monitor the physiological condition of patients anytime, anywhere, and will reduce sudden health-harmful and life-threatening incidents. Mobile healthcare monitoring systems may gather, forward, and exchange clinical information in a distributed manner. This decreases the clinical expenses for healthcare providers and chronic patients and keeps track of the physiological parameters of the patient, like body temperature (BT), blood sugar (BS), blood pressure (BP), electroencephalogram (EEG), electrocardiogram (ECG), and reduce sudden health hazardous incidents of the patient under unanticipated afflictions. Acquiring instantaneous notifications in the shape of SMS, either to clinics to interrogate patient's bodily data or even to advise patient's about required treatment or even a medical test. More thorough descriptions of selected Mobile healthcare monitoring systems (MHCMS) are shown in Table 5. Table 5 presents the reference number of systems, title of system, targeted application, technology/module, health parameters, hardware description, and in the last outcomes/description/remarks of system.

1) CRUCIAL INVESTIGATION ANALYSIS AND FURTHER RESEARCH

It is convenient for patients and doctors to access health information anytime, anywhere, and quickly in critical conditions.

TABLE 4. Remote healthcare monitoring systems.

Reference Number	HMS Title	Selective Application	Technology/ Module	Health Parameters	Hardware Description	Remarks Description
[14]	RHAHM	Remote Hypertension and Hypotension Monitoring	Wireless/UDM	BP, BT, SPo2	Body sensors/ Audio/Video cameras	In this system, researchers designed real-time RHMS and DSS to diagnose hypertension and hypotension. The designed system was tested in a real-time clinic atmosphere and didn't focus on heterogeneous environments. The system is now more expensive and still requires some work on data integrity and network reliability.
[37]	MURHMS	Multi-user Remote	Wireless/Internet	BT, HR, BP	Bio-sensor, Data card, RMD	In this system, a networked system is designed to recognize, interact, and remotely monitor the patients. Authors only focus on remotely programmable apparatus and having a lack of security.
[36]	AZBEHMS	Elderly Health Monitoring	IoT/ZigBee	BG, BT, HB	Tiny Sensors/ Smartphone	The designed system obtains, transmits, stores, and analyzes the elderly health physical conditions for healthcare providers in real time invasive or non-invasively through a tiny human wearable multi-hop sensor network.
[39]	BlueBOX	Remote-CHF Monitoring	Wireless	ECG, PPG, Bio-impedance	Hand-held	BlueBOX is a wireless hand-held healthcare monitoring system for heart clients. The system is still large and it is inconvenient and has less reliability with remote accessibility, high costly and low acceptance proportion
[42]	SmartVest	Remote Health Monitoring	Wireless/wearable	ECG, PPG, BT, GSR.	e-Textile (Vest with woven sensors, microcontroller	Smart Vest is a general purpose remote health monitoring system based on e-textile. The system is using e-Textile smart shirt to continuously monitor the serious/ high risk patients and has high speed band (2.4 GHz) and it is inexpensive having high acceptance in remote setups.
[43]	MEMSWear	Remote Health Monitoring	WBAN, GSM	ECG, SPo2, BT, BP	BS, PDA	MEMSWear is a remote healthcare monitoring which remotely monitors the vital signs of patients and integrates wireless body area network (WBAN) and personal digital assistant (PDA) phone technology and system offers high standard of healthcare with low cost.
[41]	e-Guardian	Remote physiological Monitoring System	GSM,GPRS, ZigBee	ECG, BT, FD	WMD TI, CC2480 ZigBee processor	e-Guardian is a remote physiological parameters monitoring system and likewise a home-based e-monitoring and notification system which is low-cost, small, exceptionally power saving, simple in design and operation, and durable in efficiency and having higher acceptance rate.
[44]	iCare	Remote Health Monitoring	Bluetooth/ GSM/ GPRS	BT, ECG	MD, BS	iCare is a remote healthcare monitoring system for elderly people. System could offer remote monitoring anytime anywhere and provide personalized services for each person based upon their personal wellness disorder. System is affordable having higher acceptance rate.

Therefore, mobile health monitoring systems have immense perspectives in the field of healthcare. Moreover, it helps healthcare organizations to provide cost-effectiveness, reliability, and quality of healthcare for patients. It improves the access, efficiency, and quality of clinical and business processes to the entire process. These systems will still face challenges, such as patient privacy when the patient's real-time personal information is exchanged/distributed over open wireless channels. Some unapproved people /parties/malevolent assaulters could access the personal medical records of a patient and easily inject wrong information into the medical data stream and play with patient's lives, having some drawbacks that require further research on energy efficiency, sustainability, scalability, and reliability.

D. WEARABLE HEALTHCARE MONITORING SYSTEMS

Through wearable devices, healthcare providers/medical professionals can effectively monitor the physiological parameters of patients inside and outside their homes, and they can also save a patient's life in an emergency. Detailed descriptions of selected wearable healthcare monitoring systems (WHCMS) are given in Table 6. Table 6

TABLE 5. Mobile Health Monitoring systems.

Reference Number	HMS Title	Selective Application	Technology/ Module	Health Parameters	Hardware Description	Remark/Description
[55]	IMAIS	Fetal Monitoring	JADE/ADE	Patient activities	FMD/PDA	The designed mobile multi-agent-based DIS permits programmed fetal monitoring in real-time from any place using a smartphone. The anticipated system evaluates fetal monitoring information noted distantly rendering to the medical expert's strategies. While the system only relies on Java technology and lacks security measures.
[51]	AALP	Co-Morbidities Monitoring	Short-range/ long-range. Communication technologies.	BP, Spo2, ECG	Smartphone. Actuators. MDIS, Pacemaker.	The designed smartphone-centric architecture monitors the physiological conditions of co-morbidities patients. The system is more complex and more expensive, and it has poor acceptance chances.
[62]	Dial Betis	Diabetes Self-management support system	Mobile technology. DTM.	BS	Smartphone. BSD	The proposed system analyses the security and usability of a remote healthcare information monitoring system. To advance chronic diabetes self- controlling and, thus, medical results. This research just focused on usability and feasibility, and having lack of reliability and patient privacy.
[56]	A W-Kids HMS	Kids Health Monitoring	Bluetooth	HIB. BT	AM, IT DTS. Smartphone	Health monitoring systems for children by designing. Developing and evaluating a simple wearable mobile health monitoring system for children has low acceptance rate.
[58]	IMHMS	Health Monitoring	WBSN/Bluetooth/ ZERIVC/GPRS/ EDGE	ECG. BT, Spo2, BP	Microphone. Biosensors(Accelerometer, NIBP)	The system could provide health/medical feedback to the appropriate patients through smart mobile devices based on the biomedical and environmental data collected by deployed sensors. IMHMS is a public health record administration system and doesn't have real-time personal alert system.
[5]	A 3-W CMOS	Continuous health Monitoring	WSN	BS	Glucose sensor, antenna, CI. and	The authors present an incorporated active contact lens system for wirelessly and continuously monitoring glucose levels. The system has a high cast acceptance rate.

describes the reference number of systems, the title of the system, targeted application, technology/module, health parameters, hardware description and in the last outcomes/description/patient's real-time personal information is shared/exchanged/distributed over the open wireless channels than some unapproved people/parties/malevolent assaulters could simply access the personal medical records of a patient and easily inject wrong information into them.

1) CRUCIAL INVESTIGATION ANALYSIS AND FURTHER RESEARCH

Wearable healthcare monitoring systems are vital in monitoring and managing disabled and chronic patients (elderly, kids, and younger). Meanwhile, in these systems, patients' medical data acquisition quality is low, and wearable textiles, electronic sensors, and other devices irritate long-term care patients and make them unrelaxed. Moreover, these systems still require more effective research on discomfort and irritating wearable devices to make them comfortable for users.

E. IMPLANTABLE HEALTHCARE MONITORING SYSTEMS

Implantable healthcare monitoring systems [15], [89] mainly rely on in-vivo smart devices/sensors, for instance (capsules, pills, or endoscopic cameras) and can be injected/implanted in the patient's body, such as stomach, skin, and brain arteries. These smart devices are ingestible to monitor internal diseases such as stomach/brain/liver cancer. With the help of in-vivo devices, specialist doctors can easily monitor the disease and see the patient's health status. In detail, explanations of picked implantable healthcare monitoring systems (IHCMS) are shown in Table 7. Table 7 presents the reference number of systems, title of system, targeted application, technology/module, health parameters, hardware description, and in the last outcomes/description/ remarks of systems.

1) CRUCIAL INVESTIGATION ANALYSIS AND FURTHER RESEARCH

Nowadays, these systems play a significant role in the field of healthcare monitoring. Meanwhile, implantable healthcare monitoring systems still face several challenges, such as integration, reliability of in-vivo devices, security, privacy, scalability, and minimum energy consumption, and some drawbacks that require more research.

III. CONTEMPORARY NETWORKS AND COMMUNICATION TECHNOLOGIES FOR HEALTHCARE MONITORING

This section presents and signifies the contemporary networks and communication technologies used in various HMS

TABLE 6. Wearable healthcare monitoring systems.

Reference Number	HMS Title	Selective Application	Technology/ Module	Health Parameters	Hardware Description	Remarks/ Description
[75]	AMON	Cardiac respiratory Monitoring	WBAN/GSM	BP, Spo2, CG	Wrist-worn device, TMC	AMON is advanced care and alert portable telemedical Monitor is a project which was funded by the EU FP5 Ist program. AMON is a monitoring and alert system targeting high-risk heart/respiratory patients and the system has numerous abilities such as continual collection and analysis of numerous crucial signs, intelligent multi-parameter medical emergency situation detection, and a mobile link to a clinical facility and having low acceptance rate due to higher expense.
[74]	CodeBlue	Monitoring in-hospital emergency care	WSN	Pulse oximeter, two-lead ECG, EMG	MASB MicaZ and Telos motes	Harvard uni: made a wellness research called CodeBlue which is primarily rely on WSNs technology. CodeBlue is an architecture which allows wireless monitoring and tracking of patients, pre-hospital treatment, in-hospital emergency situation treatment, stroke patient recovery and very first-responders in catastrophe response scenarios and it is an economical having high acceptance rate.
[77]	MagIC	Monitoring in clinical environments	WSAN/ Wearable	ECG	Garment (Vest with textile sensors, CEB, PDA	System is made up of wearable sensors/ devices and a portable electronic board which is used for assessment of essential vital signs based upon textile sensors and it was an having higher acceptance rate.
[5]	LifeGuard	Ambulatory physiologic monitoring system for space and terrestrial applications	Bluetooth/ Serial cables	HR, hemoglobin, oxygen saturation, ambient or BT	CPOD Device, bio-sensors and PDA	LifeGuard is a novel, inconspicuous and wearable, Multiparameter ambulatory physiological monitoring system for an area and terrestrial applications but this system has reduced acceptance rate as a result of low accuracy in outcomes.
[78]	Merritt	ECG Monitoring	Electrodes	ECG	Fabric/textile(TSPC)	Merritt is Fabric-based robust electrodes exist to supply a wearable solution for ECG monitoring clothing and having high acceptance rate because of medium cost and high integrity.
[81]	BIOTEX	Monitoring in clinical setting	PAN/ Wearable	PH sensors, Sensors for sweat rate, ECG. respiration, and blood oxygenation	Textile (Wearable Sensors)	BIOTEX is a system rely on Fabric sensing units to determine physiological criteria and the chemical make-up of body fluids. with a certain interest rate in sweat and gis4 authors make it feasible to keep track of a variety of physiological parameters together with sweat composition in real time yet this work simply remains in paper did not shows acceptance and cost.
[78]	LOBIN	Monitoring in hospital Environments	WSN((802.15.4)/ PAN	ECG, HR, M. T	E-Textile	E-Textile based hospital monitoring and location system was tested in hospital atmosphere and it was a low-cost system having high acceptance rate.
[82]	LAURA	Localization and tracking system	WSN/PAN/ ZigBee	Tracking	Distributed WSN, wearable devices and PLTS	WSN based system which perform tracking and monitoring of patients hosted at nursing institutes by making use of a wireless sensor network based on the IEEE 801.15.4 (ZigBee) requirement. Monitoring system is a general purpose and did not focus on special.
[74]	Yoo et al.	Monitoring ECG	P-ECILWSAN/ Wearing	ECG	PFCB based shirt	A wearable electrocardiogram (ECG) acquisition system prierRid with planar-fashionable circuit board (PFCB) based shirt and it is an in expensive, having higher acceptance rate.

and applications. In precise, we describe body sensor networks (BSN), body area networks (BAN), wireless body area networks (WBAN), wireless personal area networks (WPAN), wireless local area networks (WLAN), home area networks (HAN), and wide area networks (WAN), in the context of IoT-based healthcare monitoring for chronic diseases. Moreover, we compare communication technologies concerning HMS parameters (see the description in Table 8). The primary purpose of this section is to provide an underpinning of HMS networks and communication technologies for fresh researchers who start their ambition in the field of healthcare monitoring. Healthcare networks and communication

TABLE 7. Implantable healthcare monitoring systems.

Reference Number	HMS Title	Selective Application	Technology/ Module	Health Parameters	Hardware Description	Remarks/ Description
[89]	Hiuquan Fu	Vivo physiological signals Monitoring	WSN/ NWSN	ECG, EEG, Temperature	Implantable Sensors, Battery and command Receiver, Implanted and Data processor	The authors designed a Vivo physiological Monitoring system to propose ISNS (Implantable sensor network system). The system could simultaneously keep track of the fifteenth and more pets, and 2 kinds of analogue details between the sensing unit's nodes can interact. Analog signals should be transmitted to the communication node. Relay nodes need to be digitalized and package messages, then frontward to the WSN through innovation. Lesser whole measurements (<2cm3), Lesser power regulation, and bestowed product packaging would certainly make the system more appropriate and appropriate for implantable smart tools. Overall, the system has much less reputation and having higher costs.
[15]	Olive H	Continuous in vivo blood pressure measurements	SAW	BP	SAW sensor	Olive H presents the ambulatory blood pressure monitoring system which is based upon surface acoustic wave (SAW) and has the immense ability to supply efficient continuous real-time blood pressure this system is better than existing industrial systems such as catheter- tip transducers. The system is not even more affordable and has less acceptance.

technologies are the most critical components of healthcare monitoring systems and have vast perspectives in the field of health [50], [108], [109].

In numerous healthcare monitoring applications, the patient's physiological parameters are acquired from sensors that need to be connected to a health information server, a smartphone, or a concerned medical professional. The health information server recognizes whether to interact with a medical expert. In some other health monitoring applications, the medical professional is communicated directly. Every healthcare monitoring system has its network architecture so that network architecture can be designed according to the nature of the healthcare monitoring system, but the standards are similar. Healthcare monitoring for chronic diseases extends the boundary and the intricacy of current network and interaction architectures. Self-sufficiency is the most vital efficiency for CDHMS. However, the current HMS has some drawbacks regarding complying with and reconciling the present study on healthcare networks and interaction architecture features, such as heterogeneous activity, realistic nature, resource restrictions, and terrible situations.

In the vigorous perspective of the IoT in the healthcare monitoring domain, self-transformation is a vital characteristic that permits the interactive nodes and facilities exhausting them to respond appropriately to the constantly varying situation in conformation with, for example, concert goals that are often described through individuals. IoT-based HMS are proficient to intention independently and provide self-transformation results. Self-forming healthcare network procedures and autonomous healthcare service sites are more enthusiastic for self-transforming IoT. Most healthcare monitoring systems are wireless and pervasive; existing HMSs are susceptible to several malicious attacks. HMS is mainly interconnected to the real environment; the malicious man could attack a real healthcare environment to get control of a chronic patient's personal information. Hence, IoT has numerous capabilities to independently adjust various intensities of fortification and privacy while not disturbing the QoS and QoE.

A. BODY AREA NETWORKS (BAN)

Zimmerman is accepted for devising the idea of body area networks. A body area network (BAN) is a network of gadgets in, on, and around the chronic patient's body. The gadgets are either sensors/actuators or devices [18]. The body sensors can be easily injected/implanted inside the chronic patient's body. The Body Area Network is at the foundation level. Curiosity in BAN has augmented substantially in the current decade, recognizing the progress in MEMS and communication technology. Due to the rigorous healthcare monitoring application necessities in terms of security, steadfastness, energy dexterous, diminutive.

In terms of monitoring device intricacy and quality of service, the design of such healthcare monitoring networks needs advanced schemes, protocols, and algorithms with the hope of being utilized in broad-spectrum sensor networks. Healthcare monitoring for chronic disease that potentially constantly accumulates, stores, and evaluates the bodily information of a chronic individual and provides health information to concerned medical professionals has been the aim of BAN [112]. Body area networks could manage the healthcare monitoring and conveyance defies through wireless communication technology through autonomous gadgets linked with the chronic patient body. BAN is more flexible to chronic requirements. Body area networks emphasize

TABLE 8. Comparison communication technologies [18], [110], [111].

CT-Parameters	ZigBee	Bluetooth	WiFi	UMTS	NFC
Range in (meters)	1 to 100 plus	1 to 10 plus	1 to 100	30 Kilo-meters	10 to 20 cm
Bit Rate	250 Kbps 40 Kbps 20 Kbps	1 Mbps	11 Mbps	2 Mbps to 14.4 Mbps.	106 Kbps to 848 Kbps.
Cost	$15	S20	S25	< $30	> $1
Frequency Band	2.4 GHz (Worldwide) 915 MHz (United States) 868 MHz (EU countries)	2.4GHz	2.4 GHz to 5.8 GHz	1.92 GHz to 1.90 GHz (u1) 2.11 GHz to 2.17 GHz (dl)	14 kHz to 13.5 MHz
Power Usage	MI to70 mW	100 to 200 mW	400 to 700 mW	0 to 6 kW	> 15mA
Security	Secure	Low Secure	Un-Secure	High Secure	High Secure

fetching approximately fundamental alterations in the Medicare provided through intensive care units, ambulances, surgical rooms, hospitals, and residences.

B. WIRELESS BODY AREA NETWORKS (WBAN)

A wireless body area network is a significant type of healthcare monitoring network that mainly consists of smart, cost efficient, tiny, energy efficient, intrusive, or non-intrusive gadgets having wireless interaction competencies that work in the immediacy of a chronic patient body.

These smart gadgets could be implanted inside, attached, or placed around the patient's body with wireless functionality to acquire chronic bodily medical data [25]. The primary purpose of WBAN is to effectively boost performance, promptness, correctness, and constancy of interaction of smart gadgets inside, outside, and around the chronic patient body. In a WBAN, the tiny gadgets are located on the chronic patient's body or his cloths. These gadgets quickly generate an interface to chronic patients in an energy efficient connectivity manner, which lets them measure bodily parameters in numerous medicare situations. Wireless body area networks associate heterogeneous gadgets on the chronic patient's body with a main medical information handling system. These medical data are then transmitted to a chronic healthcare monitoring network, where medical specialists can evaluate the chronic patient's medical state. The medical information could be strictly treated to identify the appropriate health state of the chronic patient. Letting the bodily health information be effectively tested, managed, and transferred through the chronic patients, at residence or outside, lacking or confining the chronic patient's actions, is a significant quality of a body area network [26].

C. BODY SENSOR NETWORKS (BSN)

Body sensor networks are called body sensor networks for recording information about a single person. The field of research into body sensor networks is a recent development, and the formal definition of the term body sensor network was introduced in 2006 by Professor Guang-Zhong Yang in his book Body Sensor Networks [113]. The body sensor network is a significant network consisting of several tiny sensors that perform a patient's physiological parameters monitoring. The tiny sensors and actuators in the BSN can interact with each other. A sensor node in the BSN is chosen instead of the gateway to the BSN.

D. WIRELESS PERSONAL AREA NETWORKS (WPAN)

Wireless personal area networks (WPAN) contain devices that are very closely linked to and follow the individual wherever the user goes without any facilities. WPANs are utilized to share information over extremely short proximities amongst concerned devices in an ad-hoc fashion; no prior facilities are needed. Due to the limited breathing space and scope, they consume much less energy than their WLAN counterparts and are economical [109]. There are three classes of WPANs, the distinguishing factors being information rate, battery drain, and quality of service.

a. High-data price (HDP) WiFi,
b. Medium-data rate (MDR) Bluetooth and
c. Low-data price (LDP) ZigBee.

E. WIRELESS LOCAL AREA NETWORKS (WLAN)

WLANs present a cable television substitute for wired LANs. The three common standards are IEEE 802.11 a/b/g. IEEE 802.11 a (5.15-5.35 GHz ISM band) has information fees of approximately 54 Mbps, making use of OFDM (Orthogonal regularity branch multiplexing) and an assortment of 3050 m short-range and, for that reason, call for even more accessibility factors. IEEE 802.11 b (2.4 GHz)- WiFi has a data rate of around 11 Mbps, 60- 100 m array, and utilizes DSSS (Direct sequence spread spectrum). IEEE 802.11 g (2.4 GHz) also uses OFDM yet has a greater information fee, 54 Mbps. Since many other technologies use the 2.4 GHz band, it has substantial RF obstruction. WLANs provide a cable television replacement for wired LANs. The three usual standards are IEEE 802.11 a/b/g. IEEE 802.11 a (5.15-5.35 GHz ISM band) has data rates of approximately 54 Mbps using orthogonal frequency division multiplexing and an assortment of 30-50 m short-range, consequently calling for more accessibility factors. IEEE 802.11 b (2.4 GHz)- WiFi has an information rate of approximately 11 Mbps, 60-100 m assortment, and uses direct sequence spread spectrum. IEEE 802.11 g (2.4 GHz) also utilizes OFDM but has a higher data rate, 54 Mbps. Given that several other innovations utilize the 2.4 GHz band, it has significant RF interference [18].

F. HOME AREA NETWORKS (HAN)

A home area network (HAN) is a network contained within an individual residence that connects a person's electronic tools, from several computer systems and their outer tools to telephones, video cassette recorders, TVs, video games, home security systems, clever devices, facsimile machine and other electronic tools that are wired into the network. For remote health and wellness monitoring, a HAN includes added elements, particularly sensors (e.g., fall detectors, bed sensors, and cameras), actuators (e.g., blood insulin pump), and a personal house health and wellness System (PHHS).

G. WIDE AREA NETWORKS (WAN)

This includes networks covering metropolitan and broader areas using innovations such as WiMAX (IEEE 802.16), which was created as a wireless option for inexpensive broadband through typical user interface to the general public networks and operating at 70 Mbps at 50km theoretically; 15-20Mbps at 10km in practice. Mobile-Fi (IEEE 802.20) is a genuinely mobile broadband option that supplies high-speed wireless connectivity with movement. Cellular mobile modern technologies consisting of 2G (GSM/IS-195), GPRS, UMTS, LTE, and 4G supply comprehensive insurance coverage needed to provide seamless access to clinical solutions. For global and far away coverage, satellite systems are essential. Even more details of omnipresent wireless telemedicine modern technologies can be discovered.

The use of IoT sensor networks for chronic disease management is an expanding field of research, with commercial implementations recently becoming available to end users such as clinics, healthcare experts, and chronic patients. IoT networks used for bio-medical applications are usually designed to provide functionality that could be classified into personal and body area networks. For example, in demonstration IoT networks that track a patient's movement and cardiovascular state, the movement tracking sensors are area sensors deployed as part of the location's infrastructure [113]. On the other hand, the cardiovascular sensor is attached or in continuous contact with the patient's body, making it part of the patient's body area network. The movement tracking sensor is part of the user's personal area network but isn't attached or located on the user's body. As the IEEE body area network standard does not specify the internal hierarchy for the devices within the network, the ability to maximize energy conservation and enable devices to function before recharging or replacing the battery for a node is still an active area of research. IoT researchers will focus on a specific type of body area network, a medical body area network for use with chronic medical conditions such as diabetes, cardiovascular diseases, and degenerative nerve disease.

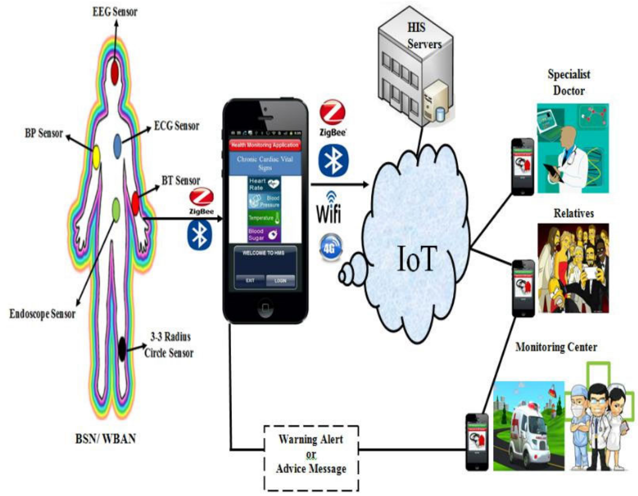

FIGURE 5. Design layout of the healthcare monitoring system for chronic disease.

IV. INTERNET OF THINGS KEY TECHNOLOGIES FOR CHRONIC HEALTHCARE MONITORING

This section provides emboldens of crucial IoT technologies for chronic disease healthcare monitoring. In particular, we illuminate IoT sensors and healthcare monitoring applications as precise in Tables 9 and 10. In addition, we explain the inspiration of IoT for healthcare monitoring for chronic diseases, the progression of the healthcare monitoring system for high-quality service, and how IoT overcomes chronic disease challenges. Moreover, this section describes the groundwork for IoT researchers to construct future healthcare monitoring for chronic diseases which is based on IoT. Designing a healthcare monitoring system for chronic diseases (illustrated in Figure 5) using smart sensors, smartphones, body sensor networks, wireless body area networks, medical information system servers, and medical web servers speeds up the technological challenges. We have listed some of them as fellows.

A. DEPLOYMENT/SERVICE COST

In the healthcare monitoring domain, monitoring services and deployment costs are alarming, and reducing service/deployment costs is crucial. To reduce the service/deployment cost, shared-node IoT network architecture can be designed to minimize the service/deployment cost of the most expensive nodes/sensors and make them affordable for all [114].

TABLE 9. IoT application in the healthcare domain.

Related Applications	Applications	Objectives/Purposes
[114]	Healthcare Monitoring System	Internet of things network architecture that could be used to decrease the monetary cost of deploying proof of concept loT sensor networks using nonaqueous, technologies.
[115]	Future Human Centric Smart Environments	The researchers define several challenges and represent the curious user-centric perspective of IoT.
[116]	Multimodal Human Monitoring	Authors experimentally present the idea of an unobtrusive wearable network of sensors and distributed control system for incorporated monitoring but this research just focus on human motion.
[38]	Energy-Efficient Healthcare Monitoring	Researchers design a healthcare monitoring system for chronic disease. The system depends on the use of Internet of Things (IoT) technologies and is best suited for patients with chronic cardiac disease.
[12]	Long-Term Health Monitoring	Monitoring the breathing pattern parameters.
[5]	Homecare Monitoring System	Ensuring the protection of the ageing experimented in a 6,14.11ejmo, healthcare unit.
[117]	Medication Control	Implement and test a health service to utilize IoT for medication control.
[118]	Drugs Interaction Checker	Design chronic patient drugs interaction checker which is based on loT.
[119]	Glucose Level Sensing	Explore the perspective of the Internet of mobile health things to detect the non-invasive glucose level of the diabetic patient.
[30]	Monitoring of Disable Peoples	Describe the role of loT to monitor the activities of disabled people.
[120]	Ambulance route search	Design and implement an effective engine for ambulance route search based on IoT.
[121]	Smart Home System	Designing and modelling intelligent home systems based on IoT.
[4]	Ambient Assisted Living	Design smart personal devices for diabetes treatment controlling in ambient assisted living based on loT.
[98]	Heart Kiosk.; Long-term Monitoring	Design and develop a family-based connected healthcare monitoring system for monitoring chronic diseases.
[101]	Vital Signs Monitoring	Introduce textile technology to monitor the vital signs of life-threatening situations.
[122]	Continuous Vital Monitoring	Assessment of 6LoWPAN competence for protected incorporation of sensors for constant vital monitoring.

TABLE 10. IoT sensors used in healthcare monitoring system.

Type of Sensor	Name of Sensor	Key Techniques
In-Body Sensor (Implantable)	Brain pacemaker, Capsule endoscopy, Glucose sensor	These sensors are seamlessly integrated with textiles through consumer electronics, and embedded in stylish smart clothes (shirts, jackets etc.)
On-Body Sensor (Wearable)	Accelerometer, ECG, EEG, EMG, Blood pressure. Esophageal pH monitor	These sensors can be injected/implanted in the patient's body such as the stomach, skin, and brain arteries and these are ingestible.
Exo-Body Sensor (Ambient)	Wall sensor, Floor sensor camera sensor	These sensors can be deployed around the physical body and might be used to determine context. For instance, a flooring resonance sensing unit was used to find fallen in the house.

B. RELIABILITY

In the healthcare monitoring system, crucial health information and medical decisions, system-wide or regional failure, are not alternatives. Monitoring devices often fail. The body area network might permit the healthcare monitoring system to blemish the network smartly by giving feedback when a data channel is no longer available. Suppression algorithms could also be included in an IoT model. Consequently, reliability is the very first concern.

C. INTEROPERABILITY

In a healthcare monitoring system, dissimilar network connections, systems, and smart tools developed by various service providers commonly utilize diverse specs and obtain various necessities. Relying on and maintaining steady communication between all connected gadgets has to be made certain when it concerns appropriate procedures.

D. ENERGY LIMITATIONS

Healthcare monitoring gadgets such as tiny sensors, smart wireless devices, and smartphones are powered by electric batteries. Battery spares are very hard to use during the communication of critical bodily data in CDHCMS; a loss/delay of a patient's medical data on time could cause the death of patients in an emergency. However, it is relatively challenging to decrease the power consumption of

TABLE 11. Different type of chronic diseases & their challenges & IoT solutions.

Type of CD	Associated Challenges	Anomalies and Reasons	Traditional Solution	IoT Solution
Cardiovascular	1. Monitoring of Cardiac arrhythmia and CHF [6]. In a cardiovascular condition. Cardiac arrhythmia monitoring is most important because a cardiovascular expert can easily determine the heart anomalies, Arrhthmia monitoring provides the normal and abnormal heart rhythm to the cardiovascular expert, to diagnose the cardiovascular patient effectively. In critical conditions, a lack of cardiac arrhythmia monitoring may cause cardiovascular patients to die.	The abnormal arrhythmias results brought serious complications such as damage to the heart vessels, muscles, and structure.	In the existing literature [133], [134], various traditional solutions are described to monitor cardiac arrhythmias such as the use of implantable medical tools for instance (pacemaker, chest belt, defibrillator), surgery such as coronary bypass, etc.	To monitor effectively cardiac arrhythmia, we have to place IoT sensors on the cardiovascular patient's body, such as the chest These smart tiny sensors automatically sense, obtain, store, and transfer cardiac arrhythmia readings through ZigBee/ Bluetooth/ WC to a main healthcare server for more interception and diagnosis purpose. Cardiovascular experts can give necessary medical advice and measures to the patient's concerns. In such a situation IoT solutions [138], show numerous advantages to cardiovascular patients and healthcare monitoring organizations. Transferring medical information information on time. Minimizing the diagnosis period are key advantage which provides necessary healthcare measures for series health conditions. It could decrease the expenses of hospitalization. Through regularly monitoring the heartbeat of cardiovascular, patients could save the life of cardiovascular patients and healthcare providers easily manage the cardiovascular disease.
Diabetes	Monitoring of blood sugar. In a chronic diabetes condition, blood sugar monitoring is essential because medical specialists can certainly identify the sugar levels of chronic diabetes. Blood sugar monitoring provides the normal and critical level of chronic diabetes specialists, to diagnose the diabetes patient approximately. In a serious health condition [135], the absence of blood sugar monitoring might cause diabetes patients to die.	High blood sugar is the foremost reason for death and many severe obstacles such as falls, Heart attacks, and brain haemorrhage.	Most of the traditional methods rely on self-monitoring of blood sugar [134].	IoT sensors can be easily implanted in the diabetes body to appropriately monitor the blood sugar of chronic diabetes. The monitoring outcomes of IoT sensors are 100% correct and save the life of diabetes in life-threatening situations [4]-[124]. IoT sensors easily interconnect through ZigBee or Bluetooth to a smartphone, transferring the medical information to HIS servers. The diabetes medical information is stored in the health information system server and healthcare monitoring actors such as patients, and diabetes experts can view it. Analyze and prescribe medication to patient's to handle their emergency condition
Obesity	Obesity is a major chronic condition which occurs due to the over body-weight or fat. Based on the World Health Organization report the observed patient has higher than 30 body weight index.	The body weight or fat brought many critical complications such as high cholesterol, higher blood pressure, high blood sugar, and some sexual diseases.	Traditionally obesity [136]. Can be preserved through maintaining body weight body weight can be controlled through balanced food intake and physical exercise strategies essential to be framed jointly with medical experts to control obesity [138].	IoT smart devices such as wearable health trackers. Ambient sensors could be attached to obese patients. Through IoT [137] devices patients. Medical professionals can appropriately monitor or track the burned calories and other activities.
Cancer	Liver cancer is a most dangerous chronic disease which occurs due to hepatitis.	High bilirubin and SGPT can bring liver failure and effective monitoring of liver function is a challenging task.	In the existing literature, regular liver function tests are conducted in laboratories to check liver function.	IoT technologies provide tiny implanted sensors which can be easily inserted/ injected into a patient's internal body to monitor the internal progress of cancer disease [139]-[140].
Asthma	Asthma is a chronic disease which may cause improper breathing. Monitoring the breath of a patient accurately is a major challenge.	Low breath in patients is a leading cause of death.	Traditionally medical experts could use stethoscopes to monitor the breath of patients.	Wearable IoT smart devices can be easily used to properly monitor the breath of patient's [141], if abnormal breathing rates occur than these smart devices [142], automatically alarm the concern medical professional to manage the emergency.

tiny sensors, smart wireless devices, and smartphone batteries in real-time patient monitoring to extend the lifespan of gadgets. Unneeded transmission of medical data through WiFi, Bluetooth, ZigBee, and processing must be avoided as much as possible. Real-time medical data gaining: In a healthcare monitoring area, the time of problems and disputes is unpredictable, and constant monitoring is needed. As a result, any risks to the undisturbed program ought to be dealt with. Possible hazards to the solution are device fault, power decrease, saturated connection transmission capability, link decline, and outside interruptions.

E. PRIVACY AND SECURITY

Almost all medical records of patients are sent in such a setting to make all confidential and can be classified. All records transferred in the system must be protected through exclusive data sources to identify patient information. Personal privacy and security are crucial factors to consider. Healthcare Internet of Things (HCIOT) is a swiftly emergent research area that has attracted foremost attention through its potential impression on the excellence of healthcare facilities and chronic patient lifespan. To facilitate healthcare Internet of things, it is desirable to incorporate Internet of Things-based healthcare monitoring for chronic diseases. The speedy expansion of IoT technologies in the current decade and their universal participation in chronic patients' everyday lives have led to innovative situations at every point in the healthcare atmosphere. The use of IoT sensor networks for chronic disease management is an expanding field of research, with commercial implementations recently becoming available to users such as hospitals, medical professionals, and patients. IoT is based on monitoring applications typically in the domains of health, physical fitness, remote patient, movement, rest ailment, convalescence, and emergency [31], [123], [125].

Numerous previous taxonomies are based upon the area of monitoring medical facilities, ambulatory, rustic regions, nursing hospices, and residence surveillance for the senior, disabled, person with a psychiatric disabled, or constantly ill people. References [126] and [127] provides the utmost detailed confederacy of health and wellness monitoring/surveillance applications consisting of persistent disease monitoring, action monitoring, event monitoring, and individual health and physical fitness monitoring. In the field of medical and computer science, IoT technologies are considered one of the hot research areas for enhancing the healthcare service quality for chronic patients [126], [127]. Healthcare monitoring for chronic diseases would provide the requisite healthcare to chronic patients in their well-known environment with little restraint. As we know, dramatic innovations are taking place in the healthcare domain, and long-term healthcare services have augmented the life anticipation for chronic patients in modern society. IoT technologies will have many applications in the healthcare sector, with the possibility of using smart devices with tiny sensor capabilities to monitor the patient's physiological parameters [118], [120], [126], [128], [129], [130]. The advantage gained is in deterrence and practical observing of illnesses, diagnosis, and providing quick health attention in cases of health complications. Wearable, implantable, locatable, readable, and addressable tiny sensors and smartphones can store patients' medical records and protect their lives in emergencies. There is great interest in using IoT technologies to support healthcare monitoring for chronic diseases in an unobtrusive, reliable, scalable, and ultra-cost-effective manner, thereby providing proper, effective healthcare services to chronic patients.

F. IOT OVERCOME CHRONIC DISEASE PROBLEMS

IoT facilitates the things in chronic patient's atmosphere to become vigorous contributors, i.e., things could share physiological data with other objects of the monitoring network or other healthcare actors. Chronic healthcare monitoring actors can easily recognize chronic patients' activities and health deviations remotely from anywhere. The quickness at which chronic cardiovascular, diabetes, obesity, cancer, and asthma have come to be common reasons for death worldwide. To manage the diseases above, we found numerous studies on IoT technologies in the recent literature addressing IoT solutions for the above chronic diseases. For instance, current research by Karlstdt et al. presents a CardioNet: A human metabolic network suited for studying cardiomyocyte metabolism [131]. Another novel study by Samii et al. provides novel implantable cardiac devices for treating arrhythmias and congestive heart failure (CHF) [132]. More critical research by Istepanian et al. represents the Internet of mobile health things for non-intrusive glucose level detection. The details of IoT solutions are described in Table 11.

G. INSPIRATION OF IOT OVER HEALTHCARE MONITORING FOR CHRONIC DISEASES

Inspiration of IoT over healthcare monitoring for chronic diseases. The influence of chronic patients' recognition inside their homes and outside and therapeutic things recognition procedures in healthcare monitoring systems, for example, patient recognition to decrease incidences dangerous to chronic patients (e.g.,erroneous medicine/dose/time). Concerning medical professionals, recognition and confirmation are often used to grant access and to increase worker confidence by addressing chronic patient protection concerns. Concerning medical resources, recognition and confirmation are generally used to meet the necessities of security measures and to evade robberies or fatalities of essential devices and goods, so in healthcare monitoring systems, recognition of patients, medical professionals,and health monitoring tools are more critical. In the whole system, the key objective of IoT is to accomplish the recognition process of healthcare monitoring players. Smart wearable, implantable sensors/devices are connected to the chronic patient body, and every sensor/device is used to accomplish chronic patients' health parameters records, medical tools, and healthcare monitoring actor's data.

H. PROGRESSION IN HEALTHCARE MONITORING SYSTEM FOR HIGH-QUALITY OF SERVICE

IoT offers a reliable real-time remote healthcare monitoring system via sensors, tags, and actuators. The sensors and tags could be attached to patients' medical devices, medical professionals, and other healthcare monitoring tools. Monitoring authorities can easily monitor all activities or operations of the healthcare monitoring system from anywhere and anytime. IoT applications in healthcare monitoring systems improve healthcare procedures, decrease dangerous health events, heighten the quality of healthcare service, and save the lives of chronic patients in emergencies.

I. IOT CONSTRUCTING FUTURE HEALTHCARE MONITORING

IoT has countless capabilities, as illustrated in Fig. 2; it delivers enormous opportunities for detecting chronic diseases and healthcare monitoring information around tagged health performers such as chronic patients, medical experts, staff, and medical apparatus. Due to the capabilities of IoT, health performers could be identifiable, monitorable, traceable, legible, and manageable. Healthcare monitoring objects might be incorporated with smart gadgets such as tiny sensors, smartphones, actuators, tags, and nodes. IoT is linked to chronic patients, medical professionals, smartphones, medical devices, and everything at all times and everywhere.

n international market report [143] estimates that 50 billion devices will be linked to the World Wide Web/Internet by 2020. Utmost smart IoT devices will be connected to medical devices in homes, clinics, and real environments to acquire, store, process, and analyze medical data [144], [145]. IoT fortifies many sensing units and healthcare items that connect to the World Wide Web/internet using Bluetooth, ZigBee, RFID, WiFi, 3G, 4G, GSM, and GPRS. In 2013, 85% of healthcare organizations determined to employ IoT technologies in medical organizations to provide more transparency and visibility into healthcare activities [ABI, 2013]. IoT applications in healthcare systems benefit by boosting 72% of shipment procedures, 66% of patient security, 63% of avoidance reduction, and 63% of transparency and visibility of the healthcare supply chain [Zebra Technologies, 2012].

J. IOT PROVIDES LONG-TERM SURVIVE

In the present decade, IoT gadgets are quickly involved everywhere, from the bed in a chronic patient's house to tiny sensors in a chronic patient's body. IoT healthcare monitoring applications deliver countless assistance to chronic patients every- time and anywhere. When smart IoT gadgets are attached to the chronic patient's body, then all the movements of a chronic patient can be monitored remotely; these IoT fundamentals augment the lifespan of chronic patients to survive long independently and comfortably.

V. CHALLENGES, OPEN ISSUES AND FUTURE DIRECTION OF HEALTHCARE MONITORING

This section discusses the open research issues that still necessitate addressing in the field of HCM. In the recent decade, rapid innovations have taken place in current technologies, but still, we found inconsistencies among the health parameter readings and the real obtaining results of health parameters. Several research studies recommend that advanced IoT technology may execute well when verified in a meticulous setting. However, it battles to comply with clinical criteria in real-life situations. As a result, healthcare monitoring systems such as traditional, remote, mobile, wearable, and implantable real-time health monitoring systems could posture severe difficulties such as reliability, interoperability, energy limitations, real-time medical data gaining, privacy and security, versatility, ambulatory habitual monitoring of health parameters records to promote healthcare, usability, dynamic connectivity, data storage and analytics, appropriate and intelligible feedback, self-sufficient behavior and ethical issues. To handle these issues, we suggest potential referrals below.

A. DATA STORAGE AND ANALYTICS

Among the most significant results of IoT is the formation of an unmatched amount of data. Storage, possession and expiry of the data come to be vital concerns. The internet consumes approximately 5% of the overall energy generated nowadays, and with the demands of the IoT, it will certainly rise additionally. For this reason, centralized data centers will have particular energy effectiveness and reliability. The information needs to be saved and used wisely for healthcare monitoring. It is essential to design intelligent/ expert system algorithms that could be systematized or distributed based on the need to make sense of the data accumulated. Cutting edge non-linear, temporal machine finding out methods based upon transformative formulas, genetic algorithms, neural networks, and various other artificial intelligence techniques are required to attain automated choice-making. These systems show attributes such as interoperability, assimilation, and adaptive interactions. They additionally have a modular style regarding hardware device design and software application development and are typically highly appropriate for IoT applications.

B. VERSATILITY

The system must integrate modern advanced equipment, approaches, or even medical data gathering and information assessment modern technologies since they emerge with only minor developments..

C. AMBULATORY HABITUAL MONITORING OF HEALTH PARAMETERS RECORDS

Health consists of bodily, psychological, intellectual, and spiritual qualities. Emerging technology can promote the adoption of and procedures to endorse mindfulness towards health. Mobile communication developments allow new elucidations to cope with health issues and support the approach to managing and precluding chronic conditions. On-action medical readings can be quickly monitored and used as the method to supply back to a patient regarding possible required modifications in their everyday actions.

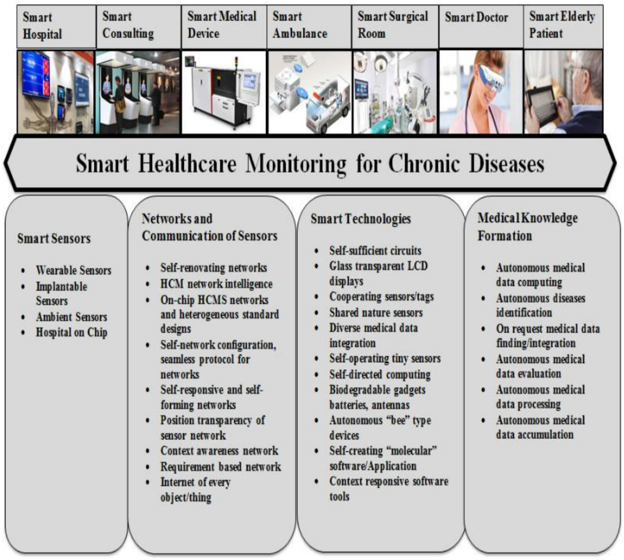

FIGURE 6. Smartness in healthcare monitoring for chronic diseases.

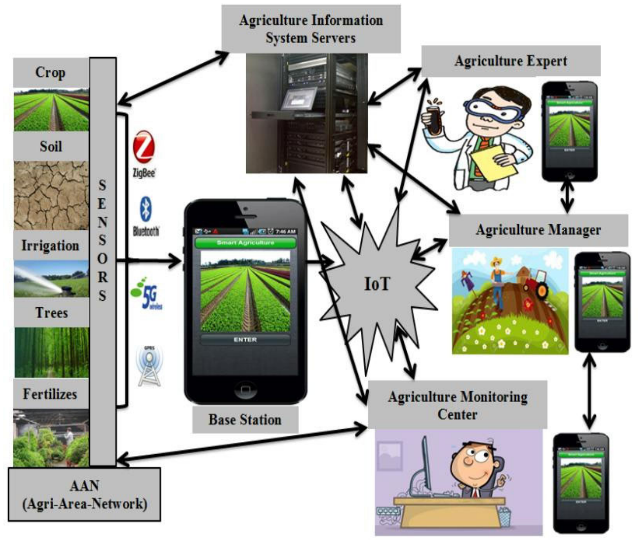

FIGURE 7. Smart agriculture.

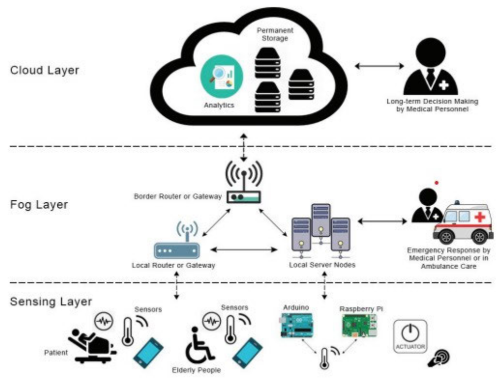

FIGURE 8. Architectures of IoT-Enabled chronic disease monitoring.

D. USABILITY

If a patient is wearing a variety of separate gadgets, then how do these gadgets collaborate into a network? Which tool is the operator? For instance, when beginning a monitoring session, it is hard to start a variety of heterogeneous gadgets in a worked style (blood sugar, heart rate, blood pressure, Spo2). Here, IoT can command allowing a master tool to coordinate the task into a Body area network or the details can be time-stamped and refined by a net-based web server.

E. DYNAMIC CONNECTIVITY

The IoT needs dynamic connectivity. Healthcare monitoring can use heterogeneous networks, but for autonomous use, connectivity often requires widespread coverage of WiFi, Bluetooth, ZigBee, 3G, 4G and 5G. IoT has dynamic capabilities to connect anything with anyone from anywhere.

F. CHRONIC PERSON MOBILITY

The mobility concern entails a seamless transition of health data from one network to another or within the exact network based upon the variation of atmosphere the patient is relocating. For instance, health applications executing on smartphones should be able to supply seamless conversion of medical information from WiFi to 5G without interference from the individual anytime he/she moves inside and outside. This conversation should be rapid; many individuals should not know of any deterioration of quality of service, such as delays. These delays cannot be endured in dangerous scenarios. The impact of mobility on the quality of service is a vital concern of the healthcare monitoring system. One essential area in managing this situation in a more comprehensive vision of IoT is situation awareness. In such situations, health monitoring systems adjust their functions to the current situation without specific individual interference. Hence, they focus on enhancing mobility and efficiency by enchanting the atmosphere into justification. This encourages health application designers to create health monitoring applications that adjust characters to the individual's situation while relocating between dissimilar networks.

G. APPROPRIATE AND INTELLIGIBLE FEEDBACK

Having obtained some relevant information, this should be fed back to the person at an appropriate time in a usable format. This can be done both synchronously and asynchronously. For example, the Nike Plus system currently provides ongoing pace messages via the auditory channel and permits the user to view trend data on a home computer. It cannot, of course, feedback information gathered from other devices such as heart rate, unless we aspire to an IoT model as illustrated in figure 8.

H. SMARTNESS IN THE HEALTHCARE MONITORING FOR CHRONIC DISEASE

In the present time, rapid developments in modern technologies such as IoT, sensor technology, MEMS, Nano-technology, mobile communications, artificial intelligence, software engineering, secure distributed databases, transparent computing, and embedded technology are shown in the literature; we hope these developments will bring smartness in healthcare monitoring for chronic diseases, as we know that monitoring the health of chronic patients is demanded worldwide. In figure 6, we ensure that IoT technologies have smart competencies such as smart gadgets/sensors, smart sensor networks and communication perspective, smart technological perspective, and intelligence in medical knowledge formation if we deploy such competencies in healthcare monitoring systems which bring smartness in the healthcare monitoring system for chronic diseases.

I. INVOLVEMENT OF IOT SENSORS

IoT sensors, such as ambient and implantable, are deployed in soil and crops. Through these sensors, agriculture experts, managers, and monitoring centers can easily monitor soil moisture, fertilizer effects, climate circumstances, and irrigation zones anytime from anywhere to increase the yield of crops and reduce crop pests. In figure 7, we present the IoT-based smart agriculture system architecture.

J. SELF-SUFFICIENT BEHAVIOR

The IoT is more convincing in sharing medical information regarding healthcare monitoring or advising the medical professional to carry out more tasks. As appropriate to a healthcare monitoring strategy or higher degree target, it brings the medical professional viewpoint into a positive approach to the healthcare monitoring procedure.

K. MEDICAL DATA FUSION

Medical data fusion describes gathering medical data from various other sensors/nodes/devices to a central point. Medical data fusion is utilized to decrease the aggregate of medical data to be transferred and the time needed for this communication. This nurtures adequate power in addition to data transfer usage. Contingent upon the network layout, the central point onwards the fused medical data to the central point. Medical data fusion could be carried out at the central point, streamlined, and dispersed. In streamlined systems, medical data fusion is employed at each sensor/node, utilizing its medical data and information from neighbors. However, in streamlined systems, all sensing units' information is directed to fuse to one central point. For a wireless body area network with star topologies around a central point, the streamlined system strategy is suitable.

VI. ETHICAL ISSUES

If all the technological obstacles can be eliminated, the IoT may raise ethical concerns, specifically in health. As information is refined into detail, an electronic image will certainly include a rich background to our lives. Take into consideration sourced training information.

VII. CONCLUSION

This paper discusses the present-day progress in healthcare monitoring systems for chronic conditions by incorporating IoT technologies. Considering the present IoT technology development in the medical field, IoT-based technology tends to transform healthcare services, offering affordable monitoring and remote medicine services. Moreover, we offer an IoT-based healthcare monitoring system capable of handling chronic diseases. In addition, the study's primary purpose is to offer a new understanding of the design and implementation of evolving systems that enhance the efficiency and accessibility of healthcare monitoring. The design of IoT-based HMS is also presented in the context of societal and technological concerns. Wrong solutions have been proposed as well. Similarly, the paper examines the potential use of IoT technology in remote chronic disease healthcare monitoring. In addition, different types of healthcare monitoring systems are evaluated, and some research topics are pointed out for future research. The results and methods of the survey paper reviewed in this document act as an instructive and constructive guide for those starting a journey to utilize IoT technologies in the healthcare field.

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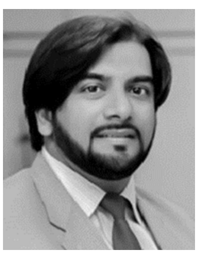

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