IoT-Based Computational Frameworks in Disease Prediction and Healthcare Management: Strategies, Challenges, and Potential

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1 Introduction

The Internet of Things (IoT) is a trending topic of discussion and research in information technology (IT) sector and even healthcare industry, because of its ability to connect various sensors and devices to form a cloud database with all available information impacting on advancement and betterment of humanity through the Internet [1]. The Business Insider report states that by 2020, 34 billion IoT-based medical equipment will be connected to the web network to create, process, and exchange huge quantities of data between web and IoT-based medical devices [2]. Internet assistive disease prediction is the development of advanced technology supported on a web-based system for the evolutionary development and betterment of electronic devices, servers, software applications into next-generation know-how practices for upbringing the medical and healthcare industry [3]. Internet technology provides a broad spectrum for better health care and clinical facility with safe and secure private data, cost-effective, time-saving, and easy to handle. The use of a server-based or cloud computing system for the generation and storage of medical and health data provides fast and easy assistance to the healthcare provider to better assist and health monitoring. Health monitoring systems include the processing and analysis of data collected from smartphones, smartwatches, smart bracelets (i.e.,

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G. Marques et al. (eds.), *IoT in Healthcare and Ambient Assisted Living*, Studies in Computational Intelligence 933,
https://doi.org/10.1007/978-981-15-9897-5_2

wristbands), and various connected devices. These sensors are essential for the diagnosis and management of patients with chronic diseases (such as hypertension and diabetes) or the surveillance and assistance of older people.

The application of the Internet in healthcare management shows a wide range of functions including:

- Rapid monitoring and diagnosis of chronic diseases with continuous health observing.
- Development of electronic health and medical records with all patients' health data and diagnostic medical information, assisting the healthcare worker for fast analysis and treatment procedure.
- Use of cloud-based servers to store the available information connected with Internet servers and medical devices.
- Clinical trial monitoring and also therapeutic drug monitoring.
- Use of sensors-based technology and devices for collecting raw health data and deals with chronic diseases like diabetes, heart disease, and cancers.
- Development of mobile health and telehealth along with various mobile phone applications used by the patients themselves for tracking their disease.

The objective of this chapter is to discuss the various strategic development and computational framework associated with the IoT-based healthcare system that is used for disease prediction, healthcare assistance, and management, based on the finding from the recently published research paper or review paper. The use of electronic health records including both cloud-based and server-based software enhances the quality and quantity of health monitoring and fastens treatment procedures. The cloud computing system is the key component of IoT-based healthcare system that collects the data, store it, process it, and analyze it to make it easily accessible. This chapter also coincides with the various remote health and mobile health technologies available for the advancement of the digital healthcare system. Furthermore, it emphasizes on the use of IoT-based techniques in combating the global pandemic of COVID-19. The advancement of the IoT-based computational framework in the healthcare system bring revolutionary changes in the advancement of the medical industries and help the healthcare providers for smooth and fasten healthcare management and health strategies. However, the limitation of data security and privacy is still a challenge for the IoT-based healthcare system and requires further future research and development.

2 Disease Prediction and Healthcare Network

Internet-assisted disease prediction is an advanced conceptuality of detection, monitoring, and fast treatment procedure based on software application and artificial intelligence trained model or electronic device for the development of next-generation healthcare advancement. Nowadays, the entire medical industry mostly based and interlinked with the uses of IoT and electronic web for the healthcare facilities. It can perform various functions such as monitoring patients health, patient's medical history analysis, digital trail monitoring, drug monitoring and also can be used for equipment and patient healthcare organization, smart patient's intake and occupancy, smart pill dispensers to monitor the patient's medicine intake and alert system.

Point of care (POC) diagnostic is used for bedside medical testing with immediate result enhances the faster treatment procedure and also help elderly, physically disabled, chronic diseases, and emergency patients [4]. For example, the use of field-programmable gate arrays (FPGA), digital signal processors (DSP), and graphics processors in ultrasound technology has reduced the size of traditional ultrasound scanners to a portable ultrasound scanner (PUS) in handheld level making easy to perform POC diagnosis, remote health care, and emergencies conditions [5, 6]. The shortage of expert sonographers could be overcome by the use of telesonography technology using high-efficiency video coding (HEVC) and H.264 encoding, where a non-expert performs POC ultrasound and is transmitted immediately to expert for diagnosis [7, 8].

Comarch Healthcare provides a wide range of healthcare solutions including IT software for hospitals, software products for radiology, remote medical care, and medical record management and expertise in IoT, artificial intelligence, cloud platform, m-Health, and cybersecurity for health care [9]. It also has been innovated various products including:

- ***Comarch Diagnostic Point***—It is the solution for a medical facility seeking to overcome the challenges, including appointment scheduling and availability, time management, and cost management. It consists of devices and software enabling quick and straightforward measurements of each patient's basic vital parameters that operate via an application available on a tablet to collect data from the peripheral device using Bluetooth and sent it to Remote Care Center [10].
- ***Comarch Life Wristband***—It is all time wearable waterproof devices with long battery life and an SOS button that enables patients to communicate and request help from the telehealth center. The sensors detect the loss of consciousness and automatically alert the telecare center. The build-in health care allows medical staff access to patients EHR and all personal and emergency data [11].
- ***Comarch CardioVest—***It is designed to perform precautionary examinations, diagnosis, and observation of adult cardio-patient. It records and transmits the ECG data to the telemedicine platform, which interprets the data and makes advance investigation about the situation and deviation from the standard [12].

The application of IoT in disease prediction and healthcare system is schematized in Fig. 1, including the use of sensor-based technology, m-health, and electronic medical records is used to obtain the primary health data of the patients that are stored in the cloud to access by the medical professional for the healthcare intervention and management.

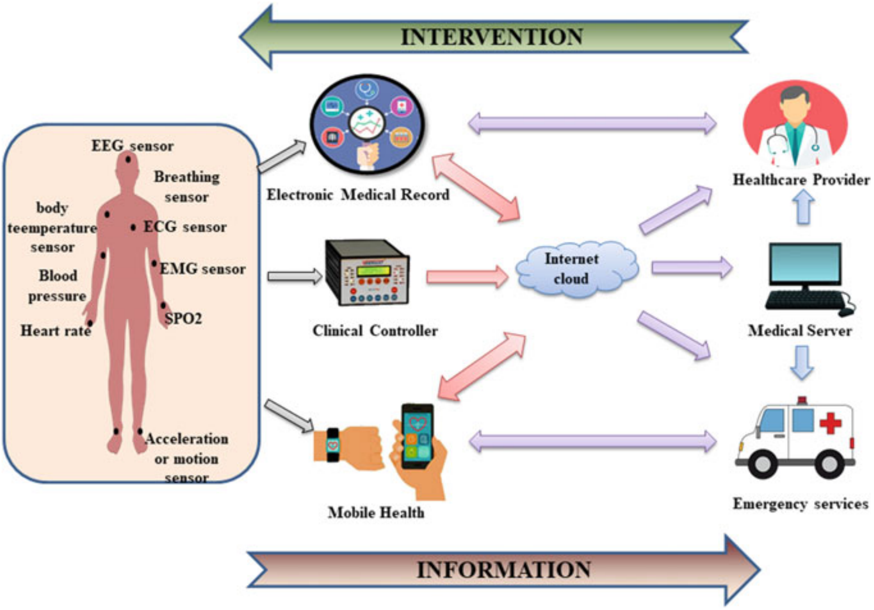

Fig. 1 Application of the Internet of things in the healthcare system

3 Medical History Analysis

The complete medical history and records are very much vital for the diagnosis of chronic disease patients, as they have to undergo multiple consultations. Electronic health record (EHR) is the real-time-based digital patient's health and medical report which can be instantly accessible to the authorized users securely. It may facilitate the availability of comprehensive information on patient health at the point of care delivery [13]. Electronic medical report (EMR) or EHR contains the patient's clinical history, diagnostics, prescriptions, treatment strategies, immunization dates, allergies, radiological images, and pathological data, providing evidence-based resources which are used by healthcare professionals to make patient care and management decisions and can also document for potential usage [14].

EMR software systems can monitor nearly all characteristics of a doctor's visit, follow all examinations, schedule appointments, and document the entire clinical findings in a way that makes it more readily available, eliminates misdiagnosis, and rapidly communicates vital details to doctors, including drug allergies, current medications, and more [15].

3.1 Cloud-Based EMR Software

The cloud-based software is easily accessible from anywhere and anytime with minimum hardware requirements, i.e., no need for maintains server or additional workstation. The data are stored in a secure cloud, thus no need for backup but has to pay monthly for use. The benefits of cloud-based EMR software are:

- It runs on a web platform, requiring no hardware or software installation preventing interruptions of cash flow and gets a faster return on investment.
- Service providers maintain all responsibility for security patches, code updates, and re-encryption.
- It contains drug libraries and intuitive decision-making tools that effectively determine and prevent medical errors.
- Highly flexible to use, can add new data and information doctors list anytime.

3.2 Server-Based EMR Software

Server-based EMR software provides on-site advantages with a greater up-front cost. It owns both software and license to install in many devices of user choice without any external support. It mainly relies on remote connection such that the user can access whenever they need. The advantages of server-based software are as follows:

- High-speed performance and support as it is an on-site system even without a dedicated Internet connection.
- The initial cost is higher due to an increase in hardware requirements and installation and for purchasing software licenses. But, over time, the expense can be less than the lease of SaaS licenses.
- It was secured by encryption of network firewalls and security controls.

The various types of cloud-based and server-based EMR software are listed in Table 1. The cloud-based software includes various packages like PrognoCIS, DrChrono, Kareo Clinical, NextGen Office, WebPT, Office Practicum, and many others. These solutions mainly serve as customized tailor-made electronic health record workflow to conveniently monitor the patient intake, appointments, patient care, clinical charting, billing, insurance, telehealth, outcome tracking, and healthcare management. Whereas the server-based software such as Athenahealth, eClinicalWorks, EpicCare, Allscripts, AdvancedMD, ChiroTouch Chiropractic provide web-based medical facilities for both healthcare and administrative management.

Table 1 List of various types of cloud-based and server-based EMR software and their functions

Cloud-based EMR software		Server-based EMR software	
Platform	Function	Platform	Function
PrognoCIS	Provides a customized and tailor-made EHR workflow to clinics and hospitals with rich and specialty-specific content. Virtual medical encounters are improved by Telemedicine	Athenahealth	Provides web-based medical facilities like patient booking, prescriptions, and also deals with practice management, care facilities, coordinatio
DrChrono	Patients' intake, medical charting, billing, and insurance management are done by healthcare personals and healthcare providers	eClinicalWorks	Provides both on-spot and virtual solutions to ambulatory practices, emergency care facilities, ACOs, hospitals, and lots of specialist choices
Kareo Clinical	Medical specialists can do patient scheduling, insurance confirmation, delinquent accounts management and the collections procedure, keeping patient records, developing customized reports, and more via	EpicCare	In large medical centers, hospitals, and practitioners give access to EMR and provide facilities to avail different specialists
NextGen Office (Formerly Known as MediTouch)	Generates eligibility for insurance, scheduling appointments, request refills, organized telehealth, and connects healthcare providers with patients directly	Cerner	Manages both clinical and administrative works as well as provides ambulatory practices or primary care facilities
WebPT	It allows therapists to generate and track patients' records, and transfer it via fax or a HIPAA-compliant portal. Manages patient appointments and reminders, medical record storage, and tracking	Allscripts	Helps to manage electronic health records (EHR), Financial issues, Medicinal chartings, and Population Health Management and also provides daily health planning, various specialist consultation

(continued)

Table 1 (continued)

Cloud-based EMR software		Server-based EMR software	
Platform	Function	Platform	Function
ECLIPSE Practice Management Software	Helps in case management by Single Doctor via "Real-Time Data Flow." Also gives access for billing, insurance claims, appointment management and reminder, and document management	Amazing Charts	Helps small practitioners and patients with bookings, billings, web-based health reports
Office Practicum	Allows to schedule appointments, managing clinical reports, testing, billing. Also plays a major role in pediatric treatments	AdvancedMD	Manages independent practices, EHR, telemedicine, relationship with patient, business analytics reports, and physician-performance rating
Genesis Chiropractic	Offers EHR, appointments, data recording, billing within a single integrated web-based system	Greenway Health	Helps to manage EHR, revenue cycle, patient care, and coordination.
The Valant Behavioral Health	Provides tools for scheduling appointments, managing clinical reports, testing, billing. Increases the efficiency in medical services by managing data, relation with patients via the patient portal	Chartlogic	Gives an ambulatory electronic health record system along with appointment, patient relations, charting, e-prescribing, E/M coding functionality
Modernizing Medicine's EHR & Healthcare IT Suite	Manages several healthcare specialists and facilities under the same umbrella and improves healthcare services	ChiroTouch Chiropractic	Facilitate both small and medium-sized practices with appointments, specialist suggestions, billing

4 Cloud Computing System

The cloud computing system is the technique of storage and analysis of large-scale data for the development of IoT-based healthcare model and database. It stores information in a network of several servers and has the adaptability of the equipment and the capacity to manage such extensive data and complex calculations and can provide continuous rich quality data in a short period of measurement [16]. Cloud providing companies uses substantial server farms and can categorize into three types: software-as-a-service (SaaS), platform-as-a-service (PaaS), infrastructure-as-a-service (IaaS), and database-as-a-service (DaaS) where they distributed computing and data management to various server farms for fast and inexpensive methodology [17, 18]. IaaS model consists of virtual machines (VM) and storage area, used for keeping data and balances computational capacity for cloud computing, and can be accessed by a user to use the software and install as per their need [19]. PaaS controls the handiness and convenience of programming models via web such that the user can use the web applications without downloading or installation of software [18]. SaaS and DaaS service models provide its user to access software deployment and databases, respectively, without any software installation or hardware setup [17]. According to the report of 2017 by "Markets and Markets," the healthcare cloud computing industry is expected to grow at CAGR of 18% within 2023 including the growth of EHRs, picture archive communication systems (PACS), vendor-neutral archives (VNAs), SaaS, and IaaS [4]. The cloud computing system relies on the fog and edge computing layers and is shown in Fig. 2. The edge computing layer servers as the source for retrieving the primary data form smart devices, EMR, smart hospital server, body sensor and forward it to the fog layer via Bluetooth, WiFi, and Internet. The fog layer is the intermediate between the edge and the cloud system.

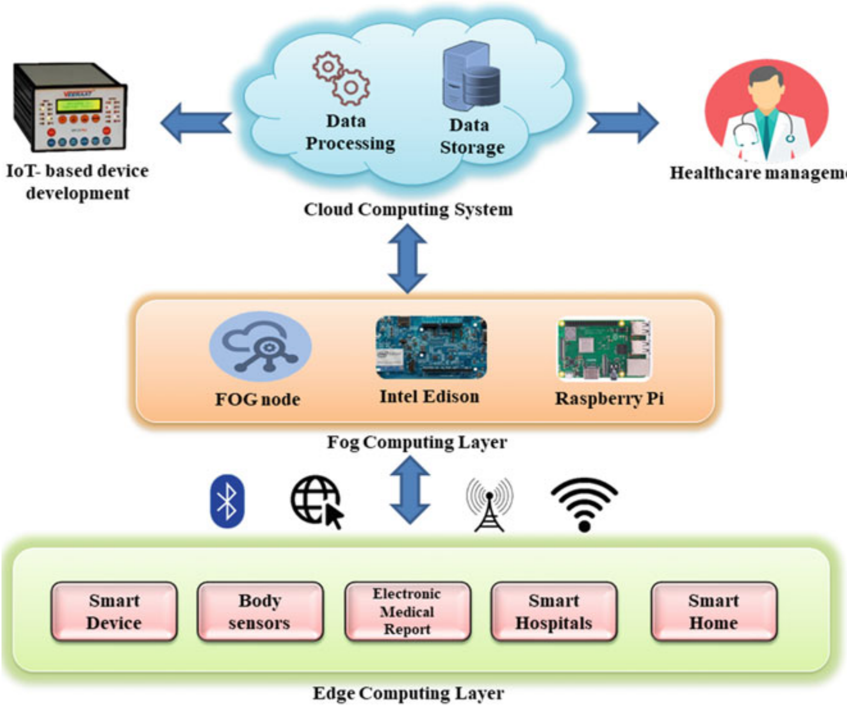

Fig. 2 Cloud computing system: frameworks and layer

4.1 Fog-Assisted Cloud Computing

Fog-assisted cloud computing system was based on the fog of things (FoT), where multiple fog nodes are connected for communication using IoT, finally, the stored data in the cloud for processing, enduring storage, and exploration [17]. Fog cloud computing is the connecting link between the cloud computing layer and the edge computing layer by enhancing the efficiency and reducing the latency to improve the quality of service [20]. It does not require computational resources, thus bringing closer to the user and reducing latencies as compared to remote cloud servers [21, 22]. Intel Edison and Raspberry Pi are fog devices that can act as a gateway between cloud and mobile clients. Intel Edison contains dual-core, dual-threaded 500 MHz Intel Atom CPU along with a 100 MHz Intel Quark microcontroller, having 1 Gb memory with 4 Gb flash storage, WIFI-enabled and used in Linux operating system. Raspberry Pi was made up of 900 MHz 32-bit quad-core ARM Cortex- A7 CPU with 1 GB RAM, WIFI connected through Realtek RTL8188CUS chipset dongle [23]. GeoFog4Health framework is employed with both Intel Edison and Raspberry Pi as a fog computing device having four different layers including cloud layer, fog layer, intermediate fog layer, and client-tier layer [17].

4.2 Edge-Assisted Cloud Computing

The edge-assisted cloud computing system relies on both data producers and consumers. It mainly consists of network edge and computer edge that reduces the latency, transmission power and also increases the analysis power [24]. The network edge nodes perform the computational tasks and service requests from the cloud, while the computer edge stores data, compute it, and translate the analysis form cloud to edge node [17]. It provides assistance to cloud backend and advantage over cloud processing in such a way that primary disease diagnosis at the edge and supervising at cloud [25]. Routers, bridges, wireless access points used as edge servers and the devices include smart devices and mobile phones working cooperatively to enhance the capability of edge computation [24].

5 Clinical Trial Monitoring

The International Council for Harmonization–Good Clinical Practice (ICH-GCP) is an international standard of ethical and scientific quality for the design, conduct, recording, and reporting of trials involving human subjects. The main purpose of ICH-GCP is to provide a unified standard for the mutual acceptance of the clinical data throughout the world. The recommendations have been established taking into account the existing good clinical practices of the European Union, Japan, the USA, as well as Australia, Canada, the Nordic countries and the World Health Organization (WHO), and they should observe when conducting clinical trials for human safety and well-being [26]. Clinical trial management software serves the task of overseeing all clinical trials, including patient records, scheduling, monitoring, analysis, and data processing.

5.1 Trial Oversight Committees

The experienced trial oversight committee is established for the security system of trail monitoring based on the mass and convolution of the trail. The trial management committee consists of the chief investigator, statistician, trial coordinator, nurse coordinator, and data manager that conduct and monitoring the path by ensuring that all protocols and standard procedures are being followed. The Trial Steering Committee supervises the trial and designs it error-free before the initiation. At the same time, the Data Monitoring Committee provides safety to trial, safeguard the credibility and validity of the study [27].

5.2 Central Monitoring

The central monitoring works in addition to the trial oversight committee for the assessment of correct entry procedures and protocol are being followed or not. It uses a statistical method for central monitoring that helps to identify the deviation from actual patterns, suggesting incorrect practices, data forgery, thus detecting target sites for further exploration [28]. It can perform the following functions:

- Range check for missing and invalid data.
- Calendar check for early indication of error.
- Test and compare data to identify trends, including digit selection, rounding, or irregular frequency distribution.
- Assessment of reporting rates and performance indicators, including the daily appointments schedule, the average length of visits, and delayed input or transmitting results.

5.3 Drug Monitoring

Drug monitoring is the method of clinically monitoring and analysis of the drug's concentration in the patient's blood circulation at a fixed, regular interval to maintain homogenous consistency and optimizing dosage regimens [29]. Therapeutic

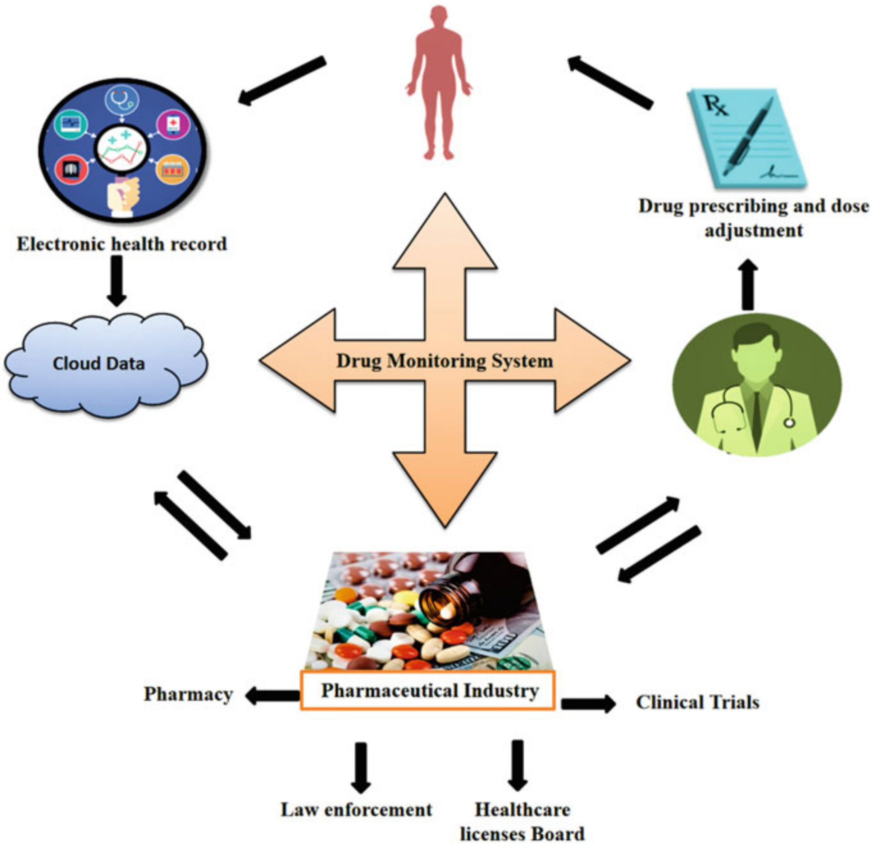

Fig. 3 Drug monitoring System

drug monitoring (TDM) is the combination of knowledge of combining knowledge of pharmaceutics, pharmacokinetics, and pharmacodynamics and is the clinical measurement of chemical parameters with proper medical interpretation for prescribing to patients safely [29, 30]. It monitors the drugs with low therapeutic ranges, pharmacokinetic variability, multiple concentration target, and causing adverse health effects based on the correlation between dose and concentration and its therapeutic effect. The system and workflow of the drug monitoring system are schematized in Fig. 3.

6 Sensor-Based Healthcare Monitoring

The sensor-based health monitoring system is focused on the information available on the health condition of the patient in the form of a digital signal, and it alerts the patient through an auditory warning [31]. Among the several types of sensors, ECG, temperature, pulse rate, and respiration sensors are widely used for continuously monitoring health. It is generally attached to the body of the patient or maybe embedded in the clothing, shoes, or watches [32]. The sensors can measure both physiological changes occurring within the body and the changes in the external environment using ambient sensors and are listed in Table 2.

Table 2 Different types of sensors used for healthcare management

Sensor type	Function in healthcare management
Accelerometer	Measure the acceleration of body movement. Record body posture and fall from bed
Humidity and temperature sensor	Contactless automatic continuous temperature monitor and control of both patient and environment
Sweat sensor	Use as a biomarker to provide information related to blood salt concentration, glucose, amino acids in the body. Used in wearable devices to monitor body fluids
Respiration sensor	Used as a visual sensor to monitor patients during MRI, surgery, also used to monitor diseases like sleep apnea or pulmonary diseases
Blood glucose sensor	Important diabetes monitoring for body glucose level. Used as a bio-implant device based on infrared, optical sensors, or ultrasound technologies
Blood pressure sensor	Continuous blood pressure monitoring. Used in wearable device
Electrocardiogram sensor	Measure the electrical impulse through heart muscles
Pulse-oximetry sensor	Uses a non-invasive system for assessing blood oxygen and hemoglobin. Attached to fingertip and now used in wearable device to measure SpO2
Sensor-enabled pills	Deals with chronic and complex disease. Ingestible pills upon consumption give vital health status to a linked wearable device and also saved in computer cloud, further used by doctors to monitor patients, diagnosis and track their activities and suitable treatment plan
Sensor-enabled smart pill bottles	Alert and record for regular pill consumption integrated with cell phone or smart device. Upon missing dose sent alert to the healthcare provider
RFID sensor	Developed for medical management solution
Electroencephalogram (EEG) sensor	Analyses the brain commotion, tumors, dizziness, and sleep problems that have been developed to identify the driver's sleepiness/anxiety management
Electromyogram (EMG) sensor	Analyze electromechanical muscle activity during contraction and relaxation to predict neuromuscular syndromes, assess back pain, and kinesiology

Tracking drugs, patients, and devices using various sensor-enabled systems become a practical and essential aspect in healthcare industries. The continuous tracking of patient health, medicine intake, and other activities of patients reduce the cost and time expenditure of healthcare providers for managing chronic disease. The sensors are now used in various wearable devices, smartwatch, fit-band, and even in smartphones with various healthcare monitoring features. The use of radio frequency identification (RFID) technology is used for health administration solutions and drug management to monitor the drug stock [32]. RFID-based smart intensive care unit (ICU) system is generated that collects medical data in a real-time order based on a three-layer sensor system for precious detection and management [33]. It consists of an antenna and an IC chip embedded along the tags containing the identification code to transfer the data upon electromagnetic field generation. The RFID-based healthcare monitoring system is very low-cost, low powered requiring minimal effort and control and can perform simple-to-execute observing and transmitting clinical data of patients [4]. WSN is an autonomous sensor capable of recording and transmitting environmental or physical data, in which each sensor is coordinated with a multi-system prototype to provide assessment and control functions [34].

7 Remote Healthcare System

Remote monitoring is the process of tracking the activities that are previously conducted on-site to increase the efficiency of analysis and speeding up time [35]. The remote patient monitoring system provides the service to the healthcare provider to access the patient's status through the use of a computer or Internet-based advanced technology. The benefits of remote healthcare monitoring are:

- Better access by physicians to increase the capacity of patient's treatment, for example, "The Care Innovations® Health Harmony platform" allows access to care for patients nationwide [36].
- It can improve the quality of care by directly connecting the patient's data with the clinician.
- It provides patient comfort and engagement and also an assurance for well-being.

The Remote Healthcare System Company provides technology solutions for design, analyze, and optimize the digital healthcare process [37]. The equipment is the interface between the human and medical device, ergonomically designed with customized parameters to facilitate functionality and development and are of following types:

- **RHS PRO**—Integrated diagnostic device with real-time clinical analyzes that protect patient health history and allow for review and medication certification.
- **RHS COMPACT**—It is a portable version of the diagnostic device with a real-time clinical review that maintains patient health history and allows for inspection and medication certification and prescriptions.

- **RHS CASE**—It is designed to be used in unusual situations or places with low geographical links. The container is stable, absorbent in shock, and transportable.
- **RHS LIGHT**—The station is designed for electromedical management and video correspondence.
- **RHS HOME**—The station is designed for electromedical management and video interaction.

CareNet is an integrated wireless sensor networking environment for remote health care, built upon a multi-layered software infrastructure having application-level routing, multi-hop packet forwarding where the data streams will be forwarded simultaneously through different threads in the system and also a mobile sensor hand-off for ensuring the reliable packet delivery and remove the duplicate data packets. It has high reliability, good scalability, extensibility, and performance, integrated into a web-based patient portal with confidentiality and privacy [38].

8 Mobile Health (M-Health)

The WHO's Global Observatory for eHealth defined Mobile health (m-health) as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices." On broad aspects, it is referred to as the use of a mobile device to collect the real-time medical data from users that are stored in the online server or cloud for access by the doctors, hospitals, insurance providers, and everyone associated with healthcare management. The application of cell phones includes the use of voice message and short messaging service (SMS), general packet radio service (GPRS), third and fourth generation mobile telecommunications (3G or 4G), a global positioning system (GPS), and Bluetooth. In a worldwide survey on m-health done by WHO on 2009, it was found that the m-health initiative is mainly categorized were health call centers/healthcare telephone helplines (59%), emergency toll-free telephone services (55%), emergencies (54%), and mobile telemedicine (49%) [39]. The application of m-health in health care includes education and awareness, disease diagnosis, outbreak tracking, remote data collection, remote monitoring, personal digital assistance, telehealth or telemedicine, and even help in disease management [40]. The use of a smartphone application or Web site is the best way for delivering m-health to a wide range of peoples as it is easily accessible, not require much knowledge, and also meager cost. The m-health applications market is expected to witness significant growth due to high consumer demand to monitor their health. It helps by reducing the cost of appointments, medication reminders, and recovery instructions. According to a report published by "Fortune Business Insights," the Global m-health applications market was $11.17 billion value in 2018 will grow at 21.1% CAGR and by the end of 2026, it will reach to $57.57 billion [41]. The various m-health applications are listed in Table 3.

Table 3 Types of m-health applications and their functions

m-health applications	Description and functions
AirStrip, AirStripOB/Cardiology	Maintain synchronization among multiple devices. Data from several EHR, many clinical solutions accessed through smartphones, tablets, and computers from hospitals, post-acute, and community-based care organizations to monitor cardiac conditions
Aetna, ITriage	Direct accession to health information and sequential treatment guidelines for patients' health issues in a convenient and effective procedure. It directs the patient on treatment procedures, health insurance schemes
Cerner, CareAware Connect	Manage multiple clinical communications on a single platform. Users can get medication information related to health issues
DSS Inc.	Provides clinical care facilities with reduced administrative costs, and designated for mobile screening tool
Epic Systems, MyChart Mobile	Helps to access data related to test reports, immunizations, medication, and health conditions from previous in-office visits of patients. Also allows to take appointments, healthcare bill payments, uploads fitness data given by patient from wearable health device
GetWellNetwork, Marbella	Accessibility to patients' data and collection by healthcare providers, hospitals, and other associated service providers through mobile devices. Integration with other vendors allows instantaneous alerts and tracking to alleviate manual follow-ups
MEDITECH, Ambulatory EHR	Helps to avail complete web charts of patients including test reports, prescriptions, appointments, progress in health condition by tapping their name. Also help identify at-risk patients by population management tools
PatientKeeper	Allows healthcare workers to order radiologists' equipments, medical personals, and similar services for their patients across all hospital departments to keep track of allergies, test results, patient vitals, and related health data as a way to achieve accuracy and to save time
PatientSafe, PatientTouch System	Helps to maintain communication within the healthcare authorities and bring them under a single umbrella to improve care efficiency
Spok, Spok Mobile	Helps to coordinate clinical care units to improve care efficiency. Integrates with current EHR systems for care responsibilities and hospital-wide scheduling via preferred devices like smartphones or smartwatches
National Health Portal India	Government of India official application with intuitive UI, which is simple, easily accessible, and provides health information to rural illiterate or semi-literate peoples
AIIMS-WHO CC ENBC	Provides assistance and help to nursing colleagues and neonatologist across small hospitals with limited resources
HealthyYou Card	Search engine and online appointment booking with alerts and reminders

(continued)

Table 3 (continued)

m-health applications	Description and functions
1mg	Online pharmacy supplying prescription medicines and OTC, along with online doctor's consultation

8.1 Telehealth and Telemedicine

The Health Resources Services Administration defines telehealth as "the use of electronic information and telecommunications technologies to support long-distance clinical health care, patient and professional health-related education, public health and health administration." The various tools include Internet accession, live streaming, storage and forward imaging, streaming media, and wireless and terrestrial communications [42].

Napier Health care provides a leverage telehealth solution to connect with patients virtually. Napier Remote Patient Management is a unified web-based platform that enables the health-workers to remotely monitoring the patient's data collected via a mobile application to manage the health condition. It is beneficial to the health-worker by allowing continuous monitoring of health indicators, clinical interventions, stratifying patients according to health conditions, and reducing paper works and management. The patients also benefitted by easy accessibility to personal data, video consultation with doctors, and increase adherence to treatment plans [43].

WHO defined telemedicine as "The delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for the diagnosis, treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities" [44]. Smartphones are now the fastest-growing market with a massive number of users and easily accessible. Consequently, the use of a mobile application for telemedicine is very much accessible and beneficial to both the user and the service provider. MDLIVE is a mobile application that connects with medical and pediatric physicians, as well as accessing behavioral and psychiatric health services. It is fast, simple, and convenient to consult with a state-licensed and board-certified physician for a non-emergency situation with waiting times of less than 15 min.

9 Internet-Assisted Healthcare Management for the Global Pandemic of COVID-19

The coronavirus disease or COVID-19 is a worldwide pandemic caused due to Severe Acute Respiratory syndrome coronavirus-2 (SARS-CoV-2), affecting more than 215 countries worldwide with 6,057,853 confirmed cases and a death toll of more than

371,166 on June 1, 2020, as reported by the World Health Organisation (WHO) in situation report 133 [45]. The first outbreak occurs in late December 2019 at the Wuhan seafood market of the Hubei province of China, and later on January 9, 2020, it is officially declared as a pandemic by the WHO [46]. Symptoms can occur 2–14 days after virus exposure including fever or chills, cough, shortness of breath or breathing difficulties, exhaustion, muscle or muscle aches, headache, loss of taste or scent, sore throat, coughing or runny nose, nausea and vomiting, and even diarrhoea. The lack of proper therapeutic drugs or vaccines created a worldwide loss of lives as well economy.

9.1 Disease Prediction and Diagnosis

Reverse Transcription-PCR (RT-PCR) is the first test for the detection and confirmation of COVID-19, but in these fast-spreading pandemic, it is not enough to counteract the emergency condition. The use of IoT, machine learning, artificial intelligence (AI) can help in overcoming the problem [47]. The Internet-assisted AI-algorithm-based automated radiology techniques like computed tomography (CT) scan, magnetic resonance imaging (MRI), and digital X-rays are used for fast diagnosis and detection. The use of deep convolutional neural network (CNN) is used to pre-train the model of ResNet50, InceptionV3, and Inception-ResNetV2 for the prediction of COVID-19 based on analysis of X-ray dataset with high accuracy [48]. The use of IoT and AI for the development of COVID-19 Intelligent Diagnosis and Treatment Assistant Program (nCapp) for providing clinical assistance based on GPU-based cloud computing system and EHR used for analysis, detection, diagnosis, and stratification of patients according to the health by the top medical advisors [49].

9.2 Healthcare Management

The situation of nationwide lockdown and home quarantine throughout various countries of the world created health mismanagement that can be overcome by m-health, and some of them are listed in Table 4. The m-health industry changed to perform the following functions:

- Medical Distancing- telehealth and telemedicine implements the contactless healthcare facility and lowering COVID-19 transmission.
- Crowdsourced disease monitoring- timely tracking and monitoring the infection, digital health experts keep surveillance on patients health data and travel history.
- Health Information Exchange to boost interoperability-development of healthcare infrastructure based on patients medical data, diagnosis, and treatment for worldwide circulation for better health management.

Table 4 Use of various m-health applications and web server for the COVID-19 pandemic

m-health for COVID-19	Developer country	Description and function
Desescalapp	Spain	All updated and simplified official information on COVID-19 de-escalation is given step by step
Smittestopp (digital contact tracing)	Norway	Accelerate the contact tracing process of a patient more rapidly and accurately. Helps to prevent more spread of COVID-19
Covidtracker	Switzerland	Tracks current and past symptoms by asking basic demographic information in Switzerland
Open coronavirus	International	A digital solution to monitor, diagnose, and contain SARS-CoV-2 infection for application of controlled quarantine measures to minimize the general quarantine of the population and restore normalcy in the shortest period
WHO Academy	International	Provides access to the WHO's COVID-19 knowledge resources all in one platform including updated guidance, tools, training, self-paced learning, and virtual workshops to boost up health-workers to take care of patients infected by COVID-19 and self-care in the critical condition
My patient sata	Germany	Detects symptoms of COVID-19, by providing a standardized questionnaire on smartphones and data given by patients analyzed by clinical IT systems providers
Vicino@TE	Italy	Allows families of hospitalized COVID-19 patients to access the clinical reports and health condition of patients. Family members can boost their moral health through positive messages
MoveUP.care	Belgium	COVID-19 patients or suspects can be coached according to the data given by them. They will receive the treatment/protocol immediately according to their symptoms (triage) by the linked doctor/hospital
Pan-European Privacy-Preserving Proximity Tracing (PEPP-PT)	International	Interrupt transmission of SARS-CoV-2 by effectively tracing infection chains rapidly via providing standards, technology

(continued)

Table 4 (continued)

m-health for COVID-19	Developer country	Description and function
EPI Salva Vidas	Spain	Coaches medical personals and state forces to use the Personal Protective Equipment (PPE) for self-protection and to protect the entire population
Triumf health	Estonia	Boosts the behavioral health of pediatric patients (7-14 yr) of COVID-19 and alleviate anxiety among children
Andama7: in-app pandemic module	Belgium	Helps citizens (especially patients, medical staff, and organization, state forces) to get updated with proper information given by trustworthy official sources. Provides medical consultation based on data collected via questionnaire
Mediktor	Spain	Provides free online self-test evaluation for Coronavirus via differential diagnosis. Also, find out other possible diseases according to the symptoms
cvPROM	Spain	Gives alerts for COVID-19 from preexisting management of Patient Reported Outcome Measures (PROMs). Helps in daily reporting by patients and/or their caregivers
COVID-19 expert	UK	Support doctors in the treatment of COVID-19 patients via clinical resources from crowdsourced information

- Surging demand for health gadgets- the fear and anxiety of the pandemic increase the use of sensor-based wearable devices and m-health applications among the peoples. Wearable provides accurate feedback on blood pressure, body temperature, and health signals that restore people's sense of control, as well as help them track their health [50].

9.3 Drug Development and Treatment

The development of therapeutic drugs and vaccines against COVID-19 is a critical challenge due to the lack of appropriate information and target. The use of computational tools, IoT, deep learning systems, and AI determines the structure and pathogenesis of SARS-CoV-2 in the human host. Genome Detective Coronavirus Typing Tool is a web-based software developed to identify the phylogenetic clusters and genotype of the SARS-CoV-2 genome and analyze in less time duration based on next-generation sequencing [51]. The use of molecular docking and molecular dynamics stimulation for repurposing the previously is used drug for targeting COVID-19 and for vaccine development [52].

9.4 Healthcare Management in India

India is the fast-promoting digitization in every field, including health care. According to the Future Health Index report of 2019, India is leading in adopting digital health technology with 76% of healthcare professionals using HER, 87% peoples with access to their HER, 80% of healthcare professionals shared this data with other associated with the healthcare industry, 46% in India use AI technologies within their healthcare practice, and 67% peoples feel easy and comfortable on digital-based healthcare technology through the use of telehealth, online consultations [53]. The Defence Research and Development Organisation (DRDO) and CSIR developed various types of equipment and technologies for combating COVID-19 and are listed as follows [54]:

- Automatic Mist-Based Sanitiser Dispensing Unit- It is based on water mist aerator technology, developed for water conservation, operates without contact, and is activated through an ultrasonic sensor. A single fluid nozzle with a low flow rate is used to generate aerated mist to dispense the hand rub sanitizer. This sanitizes the hands with minimum wastage. Using an atomizer, only 5–6 ml sanitizer is released for 6–8 s in one operation, and it gives the full cone spray over both palms so that the disinfection operation of hands is complete.
- UV-Based Disinfection Devices- Crafted and developed Ultraviolet C Light-based sanitizing box and handheld UV-C system for the disinfection of personal belongings such as cell phones, laptops, purses, money, office file cover. Defence Research Ultraviolet Sanitizer (DRUVS) was developed for sanitizing objects without using chemicals.
- Hospital Aids- It includes sample collection for testing enclosure called Econo-Walk-in Swab collection Kiosk (WISK)/High-End WISK and Kiosk for COVID-19 Sample Collection (COVSACK. It also developed Full FaceShield - Visor-Based, Medical Oxygen Plant, and Single Outlet Automatic Resuscitator.
- Mobile Virology Research and Diagnostics Laboratory (MVRDL) for remote-based COVID-19 diagnosis and testing.
- Respiratory Assistance Intervention Device: CSIR-CSIO develops a Portable Ventilator (Respi-AID) in collaboration with Government Medical College and Hospital, Chandigarh.

The Government of India has developed various other IoT-based servers, software, and platform for the advancement of digital healthcare facilities in India and is discussed below.

- AarogyaSetu- Mobilephone application developed built on a web-access platform that can use GPS tracking, Bluetooth, and proximity sensors to provide an Application Programming Interface (API) for information sharing and alert of COVID-19 proximity and management.
- Telemedicine Practice guidelines- Ministry of health and family welfare in consultation with NITI Aayog released these to legitimize the practice of remote consultation using a video call, audio, text, or email.
- National Health Stack (NHS)-A digital framework with a holistic approach to supporting digital health care based on HER, telemedicine, and m-health for Indian citizens.
- e-Sanjeevani- mobile application to support the government's plan for a pan-India telemedicine rollout.

10 Prospects and Challenges

The IoT-based healthcare system is vastly developing and used in modern times. It can help in automating healthcare workflow through healthcare mobility solutions enabling interoperability through multiple connected devices that synchronize data across each other, delivering easily accessible and low-cost healthcare management. The application of IoT for real-time data collection, segregation, processing, and delivery using an Internet-enabled mobile device for instantaneous health tracking, monitoring, alerting, and assisting patients is to provide home healthcare delivery. To motivate the full recognition of such Internet-based healthcare device throughout the aspect of human services, it is critical to identify and breakdown of precise safety and security considerations, including safety requirements, security flaws, risk models, and countermeasures, from that specific point of view. Regarding this, it is imperative to focus on the subsequent safety rations to pull off the covered service network [3]. The data privacy and security is the most significant challenge and limitation of the IoT-based healthcare system. The user data are easily prone to misuse and digitally theft, which include the duplicitous health claims, use of user information to generate fake identity, misleading with false evidence, and privacy issues. It is challenging to cumulate data for dynamic comprehensions and exploration due to the non-uniformity of data processing and communication protocols. End-users may be susceptible to malicious threats, data leakage, and malpractice upon allowing permission to third-party applications to access data. Besides, there are alternative questions about data breaches when the data ventures join the cloud storage facility of the proprietor. Internet Protocol version 6 (IPv6) is being implemented in the IoT-based system as a communication protocol to ensure confident connection among the IoT nodes in an unrelated environment through the deployment of such mechanisms.

The application of the IoT-based healthcare system brings revolutionary changes in the advancement and fastens the healthcare facilities and management. It becomes very convenient and easy to access the health data, diagnose the disease, monitor health conditions, and provide strategic treatments within low cost. The use of various computational frameworks for disease prediction conveniently increases the process of early detection and point of care delivery. The generation of the electronic health record is accessible by healthcare workers from anywhere across the globe, containing all vital information about medical conditions, allergies, previous medications, and treatment of patients. The usage of a cloud computing system is for storage, processing, and analyzing huge amounts of data into a simplified form. The remote health monitoring and mobile health make it possible to provide healthcare assistance at the extreme conditions of rural geographical areas. The development of the sensor-based wearable device, smartphone application, web servers provides its user with all necessary information such that patients themselves can track their daily health status and get advice from healthcare professionals from their home. Collectively, the advancement of IoT-based healthcare systems is the fastest growing in the medical industry and is very essential for the betterment of mankind. However, there are certain limitations, and proper training is still required in the near future to provide an error-free and convenient healthcare system.

11 Conclusion

Researchers, information technicians, and programmers across the world have tried to explore numerous technological approaches and development to improving disease prediction and treatment from current IoT-based computer assistance tools and techniques. This chapter highlighted the current strategies and available technologies of IoT-based computational framework in disease prediction and healthcare management. It focuses on the current approach of linking Internet servers and the cloud computing system with the patients' health data to generate an electronic version of it for better functioning and accessibility. With the beginning of remote monitoring technology and mobile health, it becomes easy to connect with patients all across the world irrespective of their location. The use of smartphone-based applications, wearable device sensor-based technology created evolutionary changes in the healthcare industries. Moreover, this chapter emphasizes the use of Internet-assisted technology for healthcare management and fight against the worldwide pandemic of coronavirus disease or COVID-19. The use of IoT, AI-based algorithm trained models developed for easy and fast detection of and diagnosis of COVID-19 along with the development of drugs. Additionally, this chapter established the strategies that are available and being used in India to promote the digital healthcare system. However, there are many drawbacks and limitations of IoT-based healthcare system. The availability of users' personal data may lead to privacy and security issues, and it can be theft and misuse by others for malpractice. Complete dependency on IoT-based technology may result in error within the healthcare system and even lead to misleading peoples with wrong information and fraud. The wearable devices, sensors, m-health, and other Internet-assisted computational framework might override with technical faults and dysfunctioning. Moreover, appropriate knowledge and training of the healthcare professional is required for the proper application and assessment of IoT-based technologies. Thus, this chapter overviews the various computational frameworks that are presently available for IoT-based healthcare system and opens a vast area of future research to overcome the problem of data security, privacy, and for the advancement of technology.

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