Journal of Infection and Public Health 17 (2024) 559–572

Contents lists available at ScienceDirect

Journal of Infection and Public Health

journal homepage: www.elsevier.com/locate/jiph

Review

Multirole of the internet of medical things (IoMT) in biomedical systems for managing smart healthcare systems: An overview of current and future innovative trends

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A R T I C L E I N F O

Article history:
Received 6 April 2023
Received in revised form 16 January 2024
Accepted 18 January 2024

Keywords:
Internet of medical things (IoMT)
Biomedical systems
Smart healthcare systems
IoT in healthcare
Real-time patient data

A B S T R A C T

Internet of Medical Things (IoMT) is an emerging subset of Internet of Things (IoT), often called as IoT in healthcare, refers to medical devices and applications with internet connectivity, is exponentially gaining researchers' attention due to its wide-ranging applicability in biomedical systems for Smart Healthcare systems. IoMT facilitates remote health biomedical system and plays a crucial role within the healthcare industry to enhance precision, reliability, consistency and productivity of electronic devices used for various healthcare purposes. It comprises a conceptualized architecture for providing information retrieval strategies to extract the data from patient records using sensors for biomedical analysis and diagnostics against manifold diseases to provide cost-effective medical solutions, quick hospital treatments, and personalized healthcare. This article provides a comprehensive overview of IoMT with special emphasis on its current and future trends used in biomedical systems, such as deep learning, machine learning, blockchains, artificial intelligence, radio frequency identification, and industry 5.0.

Contents

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https://doi.org/10.1016/j.jiph.2024.01.013

Introduction

The Internet of Medical Things (IoMT) is a set of biomedical tools and programs that can communicate with infrastructures for healthcare data management [6]. It has the potential to reduce unnecessary visits to hospitals and lessen the pressure on medical practices by fostering the relationship between patients and their physicians and facilitates sharing of medical records through a secure platform [39]. Medical services are getting increasingly more expensive, which is may become a significant limitation from the business point of view of. The prevalence of chronic disorders is also on the rise, which is made worse by the ageing of the global population in various regions of the world. Indeed, there is a higher chance that the present community is more susceptible to chronic diseases. Therefore, it is inevitable that an access to healthcare may become unaffordable for the majority of people. In addition to improving biopharmaceutical and healthcare practices, the IoMT, also known as medical IoT, has made it possible to treat patients virtually [7]. In particular, technologies that focus on healthcare sanitation serve to keep people healthy. IoMT solutions enable hospitals to regulate refrigerator temperatures, expedite urgent treatment, among other functions [49]. Outside of hospitals, people utilize devices that send data to their doctors, such glucometers, pressure sensors, and heartbeat monitors, to mention a few [86]. Despite the fact that such technological innovations are potentially groundbreaking, the potential benefits of the IoMT have only been recently started to be evaluated. In fact, Fortune Business Insights predicted that over the next eight years, the demand for IoMT in healthcare would significantly rise from $87.62 billion in 2022 to $852.88 billion in 2030.

IoMT innovations have resulted in a considerable reduction in emergency room waiting times. Hospital bed occupancy is tracked in real-time using RFID tags, sonar cameras, and object recognition. This accelerates the process of moving patients from the emergency room to an inpatient unit [2]. Emergency Medication Technicians (EMTs), who take patients to hospitals, may consider this information valuable. When space is a concern in one hospital, EMTs can divert the patients to the next hospitals that has space. Detection systems aid in inpatient admissions and can be conveniently used to keep track of the hospital's bloodstream, or the many types of blood samples that are available [91]. Additionally, this knowledge helps EMTs to choose the most appropriate hospital for a patient. Patients receive IoMT-enabled ID bracelets that follow them through every stage of their stay as soon as they enroll and access an emergency room [78]. In order to identify shortcomings, hospitals examine the amount of time patients spend at each step of the procedure. Advanced technique in the form of an IoMT-enabled credential that tracks cardiac output, heartbeat, pulse rate, and breathing rate may be used in urgent care treatment in the future [16]. Whenever a patient's temperature unexpectedly rises when they are waiting for an appointment, the device would send a notification informing the clinical practitioners [15]. Whereas such situations seemed hopeless in the past, cutting-edge innovations, including the creation of IoMT applications, are saving the patients from such difficulties. It is clear that technology cannot stop the ageing process or reduce the consequences of chronic illnesses, but it may increase the accessibility and affordability of healthcare. The patient's bedroom may become the primary location for medical care as a result of technological advancements. For many healthcare organizations, the future of the IoMT may be murky, but in this article, we'll explain everything individuals need to know about the technology.

Healthcare IoMT strategies

Healthcare IoMT strategies depend on medical evidence collected from sensor-based technologies including smartwatches, biosensing, and smartphone apps [58]. This real-time information assists underwriters in determining which medical interventions could be the most suitable for certain individuals, hence reducing the scope and expense of unnecessary exploratory operations. Similar to this, IoMT technology supports screening and payouts by assisting Medicare advantage providers by precisely assessing hazards. IoMT also gives health insurance companies the ability to approve interactions, including telemedicine [35]. And lastly, IoMT streamlines the claims processes. Standard complaints are processed by a number of organizations before being paid, such as the authorities, clinicians, and patients. Reimbursement is accelerated by monitoring of requests across the procedure. Cryptographic protocols might be used in the future to expedite underwriting using real-time, IoMT-provided data in the context of medical coverage [30]. As a result, there wouldn't be a need to draft legal documentation, saving money that might be conveniently passed along to coverage users. With ground-breaking innovations like robotic insulin delivery, connected inhalers and contact lenses, Parkinson's disease monitoring systems, oximeters, anxiety and attitude trackers, and many more, IoMT technology undoubtedly has aided medicine [17]. IoMT has streamlined operations while raising patient satisfaction. Accessibility, increased involvement, and a drop in in-person doctor visits can all benefit patients. Therapists have profited from more accurate statistics, speedier diagnosis, and better time management. Undoubtedly, the use of IoMT in healthcare will lead to even more innovations that will simplify the working of medical industry for both doctors and patients. Fig. 1**.** gives the over view of IoMT in the context of patient wherein different modes of technology is emended such as artificial intelligence (AI), block chain (BC), cloud computing (CC), 5-G networking and bigdata analytics etc.

IoMT, which has emerged as a game-changing strategy and offers a myriad of content and capabilities, has advanced penultimate communications [56]. It makes it possible to connect a lot of different devices together to create a uniform platform for multiple users. It is crucial to carefully investigate this quickly developing invention and its applicability across numerous fields given its recent fast expansions. It serves as a stimulant for the creation of fresh means of interaction among objects and humans. The major strength of this idea is its enormous influence as a result of the creation of a brand-new broad overview. Low-cost sensors, quick and error-tolerant data lines, clever computations, and a wide range of uses are needed to build a large-scale IoMT. The basis for next-generation healthcare is, in fact, providing remote access to a large number of IoMT equipment. Currently, the research domains involving IoMT

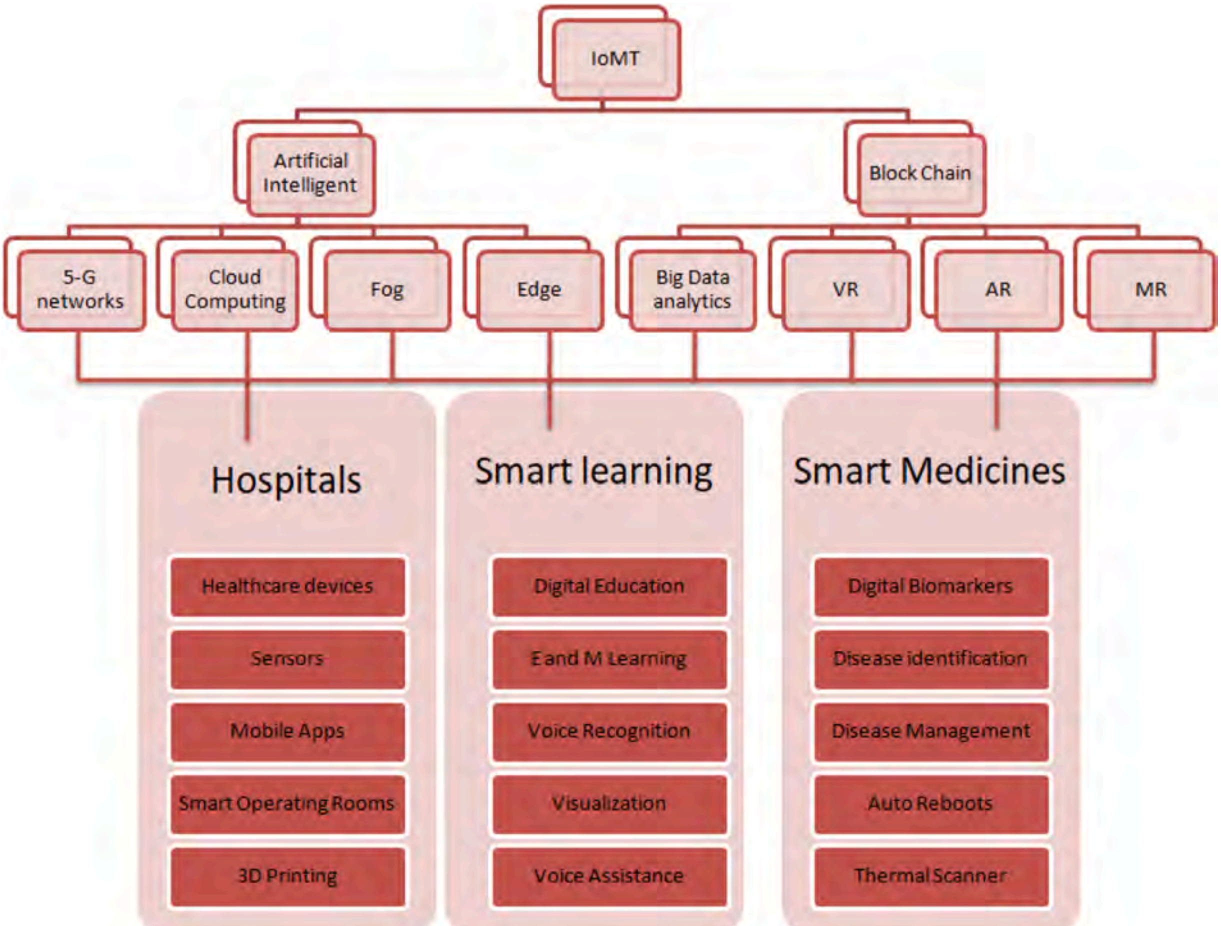

Fig. 1. Overview of IoMT in the context of patient data.

applications in healthcare are the most challenging [94]. Nevertheless, accuracy, dependability, and efficiency of electrical equipment are being improved through the IoMT [84]. Going to the doctor for even the minor issue would be highly risky given the pandemic situation. As a consequence, we can effortlessly use IoMT technology to keep track of our daily patient records, giving us the freedom to take the initial necessary actions on our own.

An IoMT-based m-health system entails a collection with several intelligent health devices that are connected to one another over the internet [84]. The IoMT architecture provides the foundation for a multi-stage intelligent healthcare system [37]. First, to gather medical data from the patient's body, a body sensor network (BSN) or wireless sensor network (WSN) may be employed to link intelligent wearable or implanted devices together. This information will then be transmitted through the internet to the portion that handles the prediction and analysis process. After gathering the medical data, evaluations may be done using the relevant massive datasets and recommendations. Major concerns can be resolved by calling doctors or other healthcare providers with the use of AI-powered programs on cell phones.

A healthier life and better healthcare are made possible by several advancements in smart home technology, especially for the elderly and those with impairments [22]. These renovations also provide patients receiving home care with a pleasant lifestyle and keep them out of hospitals, treatment centers, or other restrictive facilities. IoMT improves medical care for patients travelling from various locations outside of hospitals, reducing stress, anxiety, and isolation in hospital wards, the detail implementation is mentioned in Fig. 2. Additionally, based on their patients' health indicators,

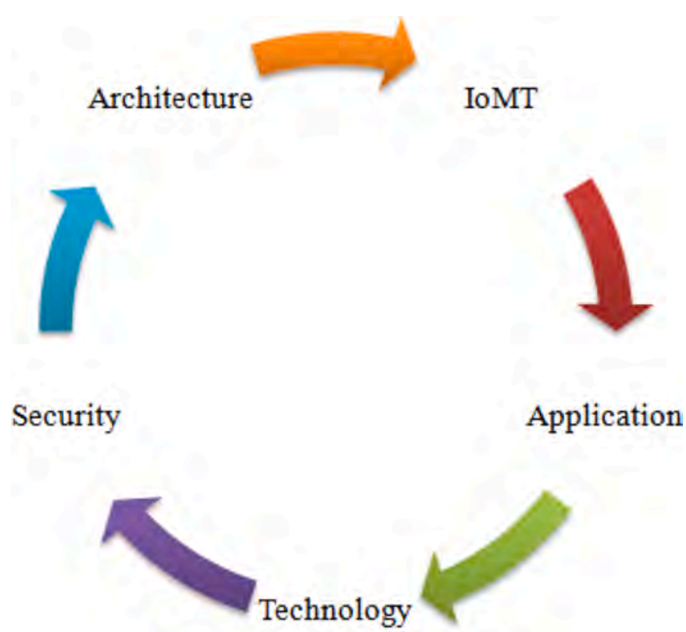

Fig. 2. Multiple aspects of usage of IoMT for medical purposes.

doctors may remotely access, evaluate, and prescribe drugs to them. Furthermore, due to the rapid advancement of new technologies and software in IoMT, individuals, specifically those with disabilities, may easily access certain household appliances via a variety of smart

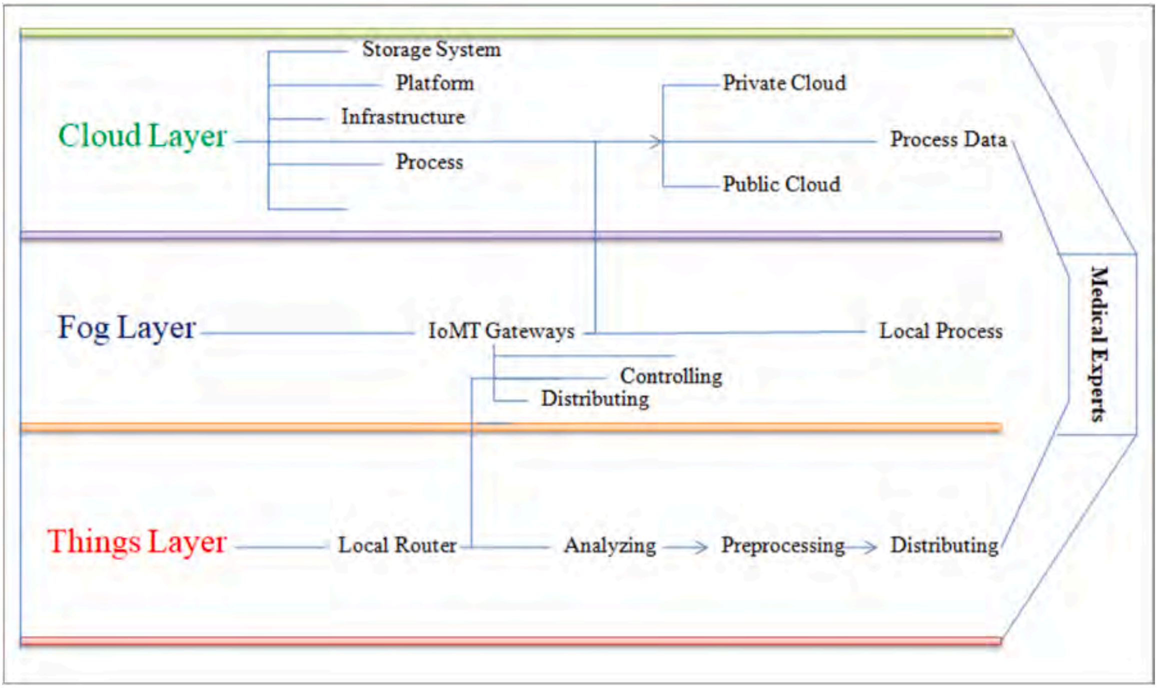

Fig. 3. The structure and functions of each layer of IoMT architecture.

devices, such as smart phones, computers, tablets, etc. [6]. Currently, IoMT is being used by around 60% of healthcare organizations worldwide [89]. In the context of the digital revolution, which puts cutting-edge technological and networked items in consumers' hands and improves access to medical services for doctors and patients even in the most underdeveloped and perhaps isolated areas, traditional health care is going through a paradigm change [36].

IoMT architectures

An internet-connected network connects a variety of intelligent medical instruments to one another to form an IoMT-based smart healthcare system [6]. There are several stages that make up an IoMT conceptual model intelligent healthcare system [35]. First, diagnostic information will be gathered from the patient's body utilizing smart sensors built into wearable or implantable smart devices that are linked by BSN or WSN [18]. The following element, which deals with the prediction and analysis phase, will receive this data when it has been transmitted online. A suitable Intelligence normalization and interpreting approach may be used to analyze the information after obtaining the clinical records [42]. Smart AI-based tools on devices can be used to contact physicians or other healthcare needs in the event of major issues [29].

According to Sun et al. [85], the application, perceptual, and network layers make up the majority of the IoMT architecture as mentioned in Fig. 3 and its usage is shown in Fig. 4. The lowest layer, known as the perceptual layer, is dedicated for gathering the data from the source and drawing conclusions about the data gathered. The access control sublayer and the data collection sublayer are the two sublayers that make up the perception layer. The data collecting sublayer's major function is perception from the acquired data, for which it employs a number of medical perceptions and signals gathering techniques. The primary methods for signal collection include graphic code, RFID, GPRS, and others. The connection sublayer communicates the data collected from the various sensors level to the network layer using short-range data transmission techniques as Beta, Wireless Fidelity, ZigBee, etc.

The responsibility for providing a variety of platform- and interface-related features as well as a variety of data acoustic communication falls on the intermediate layer, or internet protocol [61]. This layer is made up of two layers: the service layer and the high bandwidth layer. The data transmission sublayer uses communication networks, the internet, the internet of things, etc. to convey data collected from the perception layer in an accurate, consistent, real-time, and barrier-free way [31]. However, the service layer enables the connectivity of many networks, information description formats, information repositories, etc. [74]. For these integrations, it provides open interface services and a number of other platform-related activities.

Four configurations for IoMT-based smart health sector have been observed, the majority of which include three layers. According to Abdulmohsin Hammood et al. [1], architecture alone has a four-tier structure. We may conclude from a comparison of all these architectural designs that the sensors closest to the human body will be found in the lowest layer. We require a few layers in the architecture's midsection for the creation, archival, and data processing functions. Services for end users may be provided via the uppermost layer.

Health domain and its application

IoMT technology has recently advanced, making it feasible for medical equipment to do real-time analyses that were previously impossible for doctors to perform [32]. Additionally, it has helped healthcare facilities serve a larger population at once and do it at a low expense. The use of big data and cloud computing has also improved the reliability and simplicity of doctor-patient interactions. This led to a greater level of patient involvement in the healing process and a less financial load on the patient. The evolution of IoMT solutions, which would include illness diagnostics, personal care for young and old patients, control of health and fitness, and

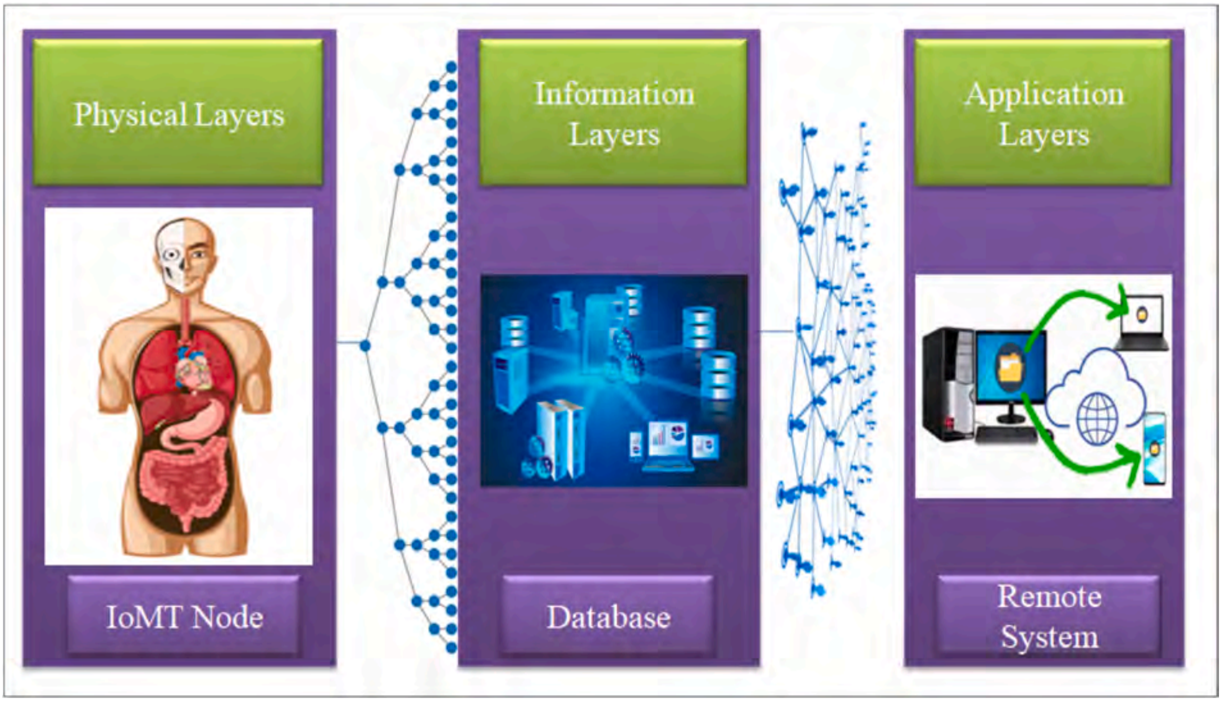

Fig. 4. Architecture for IoMT.

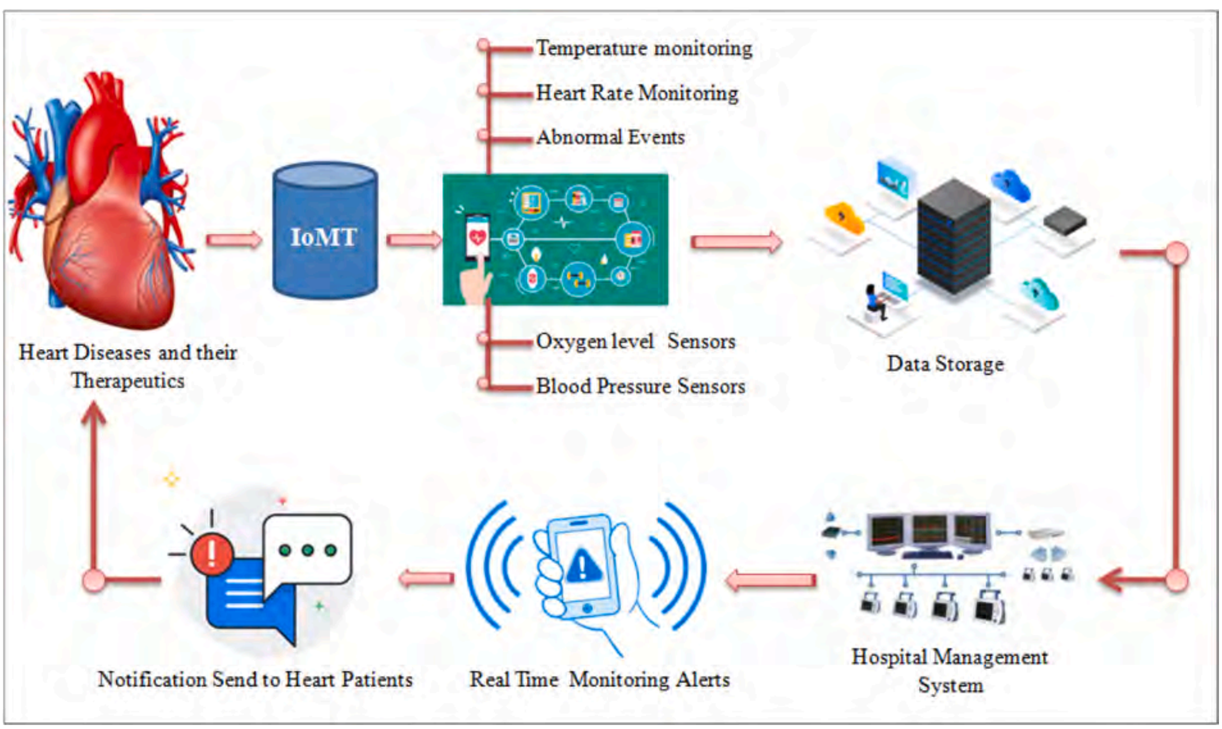

Fig. 5. IoMT-mediated assistance in services and applications for patients' health.

monitoring of degenerative illnesses, is being aided by the significant influence of IoMT that has been seen considerable advances in recent decades. It has been separated into two fundamental areas, namely services and applications, to help understand these implementations better, as shown in Fig. 5. Healthcare implementations in either the identification of a particular health issue or measures of physiological variables are included in the latter. The former covers the principles that were employed when designing an IoMT device.

IoMT and smart e-healthcare

IoMT systems are made up of sensors and devices that are tied to one another through a network of cloud environments using high-speed internet as mentioned in Fig. 6. The large storage space on cloud networks receive unprocessed data that has been acquired by these devices/ sensors. To acquire more insights, this data is cleansed further and afterwards evaluated. This necessitates the use of new programs, devices, and tools that may improve viewing, interpretation, transmission,

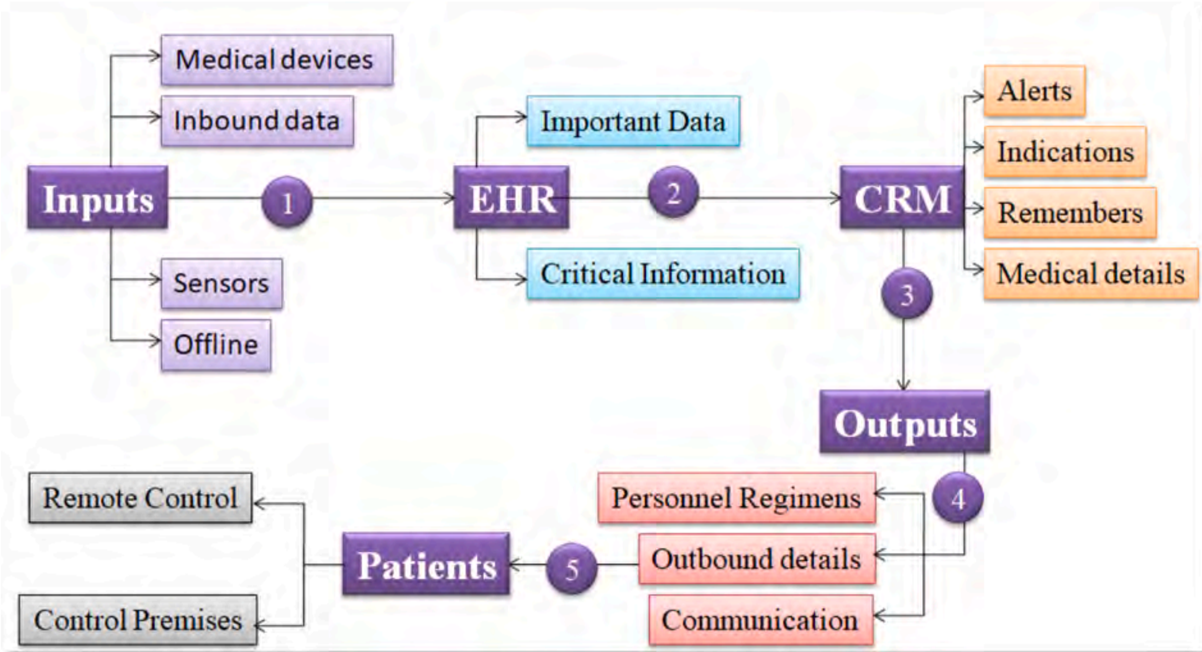

Fig. 6. Integration of IoMT with EHR (Electronic Health records systems) and CRM (Customer Relationship Management) System.

and administration of the data. A multitude of sensing devices or sensor pairs is used in every discipline. A variety of sensors may be used by smart health systems to monitor the client's vital signs [41]. A pedometer is the first sensor used for self-care, and it is employed to assess variations in constant acceleration and is useful in detecting shifts in the patient's position or the movement of any other patient body part, as well as the patient's or the observer's blood glucose levels. To gauge physiological inclination, an accelerometer measures rotational inertia [53]. When necessary, it will emit a siren to alert specialists to any issues. A magnetometer detects magnetism and its corresponding direction. In devices for geriatric care, combining it with spinning machines and accelerometers is a typical practice [92]. While the LM35 sensor normally measures the subject's body temperature and adjusts its voltage in reaction to changes [57], the DHT11 sensor measures the ambient temperature and humidity [83]. DHT11 utilizes less energy than LM35. To create an ECG (Electrocardiogram), a little chip called AD8232 analyses the cardiovascular action [46]. The MAX 30105 is a monolithically integrated sensor that measures heart rate between 1.8 and 3.3 V using two LEDs in a single photodetector and low noise converter boxes [76]. The correct shoulder posture is checked by using a body composition sensor called the ADXL335 in order to prevent problems like pain, emphysema, and breathing problems [11].

Hospitals are referred to as "intelligent hospitals" when they integrate automated and optimized components (perhaps based on AI/ML) on technological infrastructure to enhance consumer care operations and offer new services. Among the many applications of smart hospitals are telemedicine, eHealth, and online robot surgery. While telemedicine is utilized to give medical intervention at a distance, it concentrates on delivering non-clinical care remotely [50]. In remote robot surgery, automated systems perform surgeries while a surgeon operating elsewhere controls them [98].

The CRM then makes the tools for the data analysis available and designates the data to the proper aim. The CRM system receives the necessary data and information from EHR systems and processes it. These metadata produce additional triggers for patients and doctors across the ecosystem. Hospitals and medical professionals communicate with the patients outside by sending them individualized healthcare regimes. The same CRM software in the ecosystem notifies the physicians as well as other medical personnel of the notifications or other notifications.

AI in IoMT

IoMT uses of AI, such as Natural Language Processing (NLP) and Machine Learning (ML) in e-healthcare. NLP and ML have numerous applications in e-healthcare:

- Clinical Documentation: NLP can be used to automatically extract information from unstructured clinical documents, such as physician notes or discharge summaries. ML algorithms can then analyze this data to identify patterns, extract relevant information, and populate electronic health records (EHRs) or clinical databases. This reduces the time and effort required for manual data entry and improves the accuracy of clinical documentation
- Medical Coding and Billing: NLP and ML techniques can automate the process of assigning appropriate medical codes to patient diagnoses, procedures, and treatments. By analyzing clinical notes and other relevant data, these algorithms can accurately match the documented information with the appropriate billing codes, streamlining the coding and billing processes and reducing errors.
- Clinical Decision Support: NLP and ML can support clinical decision-making by analyzing patient data, medical literature, and treatment guidelines. These algorithms can extract relevant information from medical literature, interpret diagnostic test results, and provide evidence-based recommendations to healthcare providers. This helps in improving diagnostic accuracy, treatment planning, and adherence to best practices.
- Chatbots and Virtual Assistants: NLP and ML play a vital role in the development of chatbots and virtual assistants for healthcare. These conversational agents can understand and respond to natural language queries, provide basic medical advice, schedule appointments, and offer personalized health recommendations. By leveraging ML techniques, these systems can continuously improve their responses and adapt to individual user preferences.

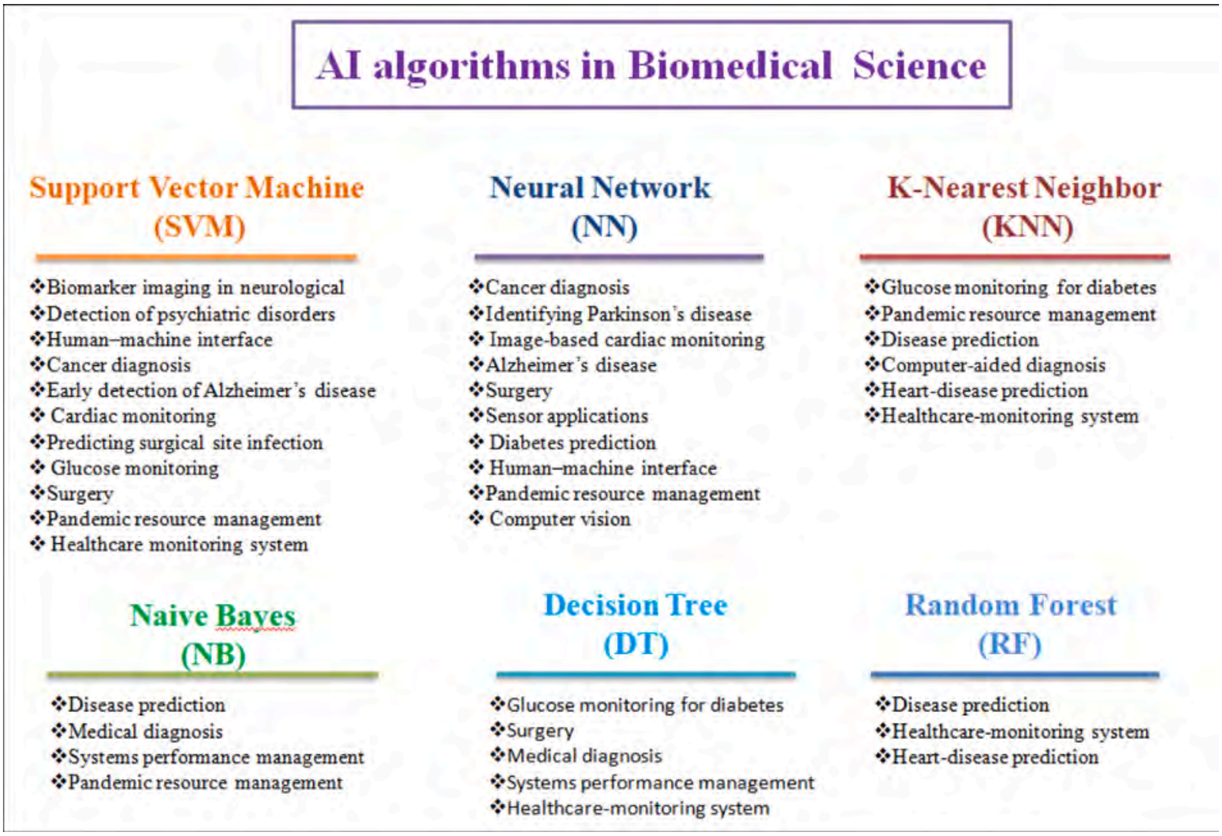

Fig. 7. Significance of AI-based methodologies in diverse medical areas.

Modern diagnoses and individualized treatment plans need to be delivered quickly in pharmacogenomics [75]. AI provides real-time solutions in identifying novel paths for addressing specific ailments relying on historical and current data (Fig. 7). Using AI-based solutions, the many components of the healthcare ecosystem may be changed. These will include AI methods for building processors that automatically record healthcare data, schedule medical visits, decide on lab testing, drug treatments, drugs, and medical interventions, among other things. By receiving further training, these categories could aid decision-making processes. In the architecture for other classifiers, such disorganized data points that are unable to be digitized can be understood using techniques provided by NLP [93]. These might be in the form of test results, notes from a physical exam, notes from a surgery, and other information pertaining to patient discharge. Machine learning also has the ability to forecast the future using data from the past. It makes the use of controlled, uncontrolled, or reinforcement learning to predict future events).

Utilizing the medical data & patient histories, intelligence solutions are also tailoring the most efficient treatment strategy as well as specific prescriptions for people. Healthcare practitioners may simply check and receive information on patients' heart rates and energy levels using monitoring devices sensor technologies. An AI-based technology is employed to analyze data and identify abnormalities in specific persons since the amounts of information is large and comes from several sources. Similar to this, in hospitals, information gathered from patient-specific health monitoring equipment can identify potential crises and notify medical personnel [21]. Healthcare system monitoring is already utilized in certain nations, such as Norway and Denmark, to identify therapeutic errors and ineffective workflow processes [64].

In this approach, AI helps the healthcare system by reducing effort, avoiding inaccurate diagnoses and unnecessary patient hospitalizations, and saving patients' time and money by cutting out pointless visits. The experience and understanding production of DL models requires the collection of investigative data as input datasets [34]. For example, operational neuro-imaging data obtained from Alzheimer's patients and computed neuro-imaging scans for emphysema are used as input files for AI-assisted diagnosis of lung cancer and Alzheimer's disease, respectively. An accuracy of 100% for cognitively normal, 96.85% for suffering from memory complaints, 97.38% for early moderate cognitive impairment 97.43% for late moderate cognitive impairment 97.40% for severe cognitive impairment, and 98.01% for AD was obtained from the subject-level characterization for 138 subject matters for affiliated stages of dementia. Identification of the data patterns is also aided by the input data gathered over time. With 94% reliability, a DL model created by Etemadi et al. using 40,000 previously accessible CT images surpassed experienced radiologists in the detection of lung cancer early [70]. These methods will aid in the early diagnosis of lung tumors, which is crucial for healthcare given that only around 30% of lung cancers are discovered in their beginning stages, which leads to a low success rate.

Pancreatitis and prostate cancer have both been studied using DL models [67]. The sensitivities of the DL modelling method developed by Alexander et al. were 50.9%, compared to 22.4% for the commonly used technique focused on breast cancers. The sensitivities of this DL framework were 50.9% against 22.4% for the commonly utilized approach based on breast malignancies. Mohammed et al. [59] and Qureshi et al. [73] developed DL models based on CT scan data with accuracy scores of 80% and 86%, respectively. There have been similar examples of AI heart problem detection using ECG data. Using only ECG data as an input for the DL model, Akbilgic et al. [4] achieved an area under the receiver operating parameter (AUC) of 0.756 (0.717–0.795). This value increased to 0.818 (0.778–0.859) when are using outcome of the ECG-AI model, as well as age, gender, race, body mass index, smoking status, commonplace cardiovascular

Table 1
List of sensors and their application in the smart healthcare system.

Sr. no.	Name of sensors	Belonging domain	Description	Applications
1	Accelerometers	Home care	Measures acceleration	Recognizes different actions and proprioception as well as blood glucose levels.
2	Gyroscope	Acute care	Detects angular velocity	Offers an alarm system for a troubling situation and recognizes human tilt.
3	Magnetometer	Acute care	Detects magnetic field and relative orientation	It is typically utilized in older devices and is designed to detect actual accidents when combined with a magnetometer or an altimeter.
4	LM35	Selfcare	Senses body temperature	This detector adjusts energy according to centigrade temperature fluctuations. It is employed to monitor body's temperature.
5	DHT11	Selfcare/home care	Humidity and temperature sensor	This instrument can measure temperature changes between 0 °C and 50 °C and moisture levels between 20% and 90%. It is a 5% accurate sensor that uses little energy. It gauges the state of the surroundings.
6	AD8232	Home care/acute care	Electrocardiogram sensor	It analyses cardiac impulses regardless of the subject's physical state.
7	ADXL335	Selfcare	Body position sensor	These sensors aids in optimal placement to avoid a number of concerns, including breathing issues, bodily aches, inflammation, and discomfort.
8	MAX 30105	Selfcare/home care	Sensor monitors heart rate	In to keep track of heartbeats within 1.8 V and 3.3 V, this optoelectronic sensor with 2 LEDs in single photo detectors generates low noise analogue input.

disease, diabetes mellitus, systolic pressure, and heart rate as A different DL model developed by Manickam et al. [55] achieved 95% accuracy in identifying malignancy areas in CT scans, as opposed to the average accuracy rate of 65% for radiologist. When CT scan data failed to disclose any abnormalities, the developed DL model assisted in the diagnosis of lung cancer [80].

In the healthcare system, AI methods are used to screen, diagnose, and project outcomes for a variety of illnesses utilizing clinical, laboratory, and demographic variables. AI may assist with the availability of resources, the finding of resources, extensive monitoring, surveillance, and the forecasting of serotonergic pharmaceuticals with recently proposed medications [88].

An increasing corpus of research is being done on AI in healthcare. In the literature, the incidence of AI application has been ranked from highest to lowest for cancers, neurological system, peripheral nervous system, integumentary framework, pregnancies, gastrointestinal system, cardiovascular system, skin, reproductive systems, and nutrition. A tool powered by AI that enables a pathology lab to identify, rank, and evaluate the digital transparencies of prostatectomy core needle biopsies [52]. A double-blind verification experiment using IBM Watson's AI technology may aid in the identification of cancer [63]. AI algorithms used to analyze and recognize different types of malignant melanoma from medical images [71]. An earlier research by Farina et al., [26] also details how upper-limb prosthesis were operated using an offline man-machine interface that employed neurons' action potential discharge times. Additionally, using data from clinical research, congenital malformations were recognized with better accuracy, and AI was also harnessed to use ventricular scans to diagnose cardiovascular problems. The "Arterys" Cardio DL software has received FDA certification and bases its robotic, changeable ventricular segmentations on conventional cardiac MRI data [13]. Similar to this, long non-coding RNAs were used to detect abnormal epigenetic alteration of stomach cancer using AI [33]. An AI-based electro diagnosis optimization strategy was developed by Prabhakar et al. [72] to locate neurological impairment.

IoMT and integrated technologies for smart healthcare system

Virtual reality (VR) is a key tool for medical diagnosis

Applications in the fields of biomedicine, amusement, business, training, and simulated, hybrid, and augmented reality are all possible. Virtual reality (VR) technology offers a three-dimensional attractive multimodal landscape, giving users of augmented reality interactions a sense of "presence." A head-mounted display (HMD) with a close-proximity screen is worn by users of therapeutic augmented worlds to provide the impression that they are being transported to a three-dimensional, realistic environment. To accomplish its objectives, VR combines intellectual concepts, elimination training, the gate-control concept, and the spotlight implication of attention. VR has been used in the diagnosis and treatment of obesity, stroke palliative care, and psychiatric & anxiety issues. By affecting biological and psychological processes, VR serves as a supportive tool for therapy surveillance in cancer patients. It lessens cancer-related symptomatology and also helps the patient feel better emotionally as a result [10].

Individuals with mild intellectual disabilities may feel less anxious as a result of VR-induced distant memories. For example, Oxford VR addresses anxiety as well as the signs and symptoms of psychiatric issues [27]. VR can be useful in delivering medical care and reducing the negative effects of the current pandemic through video chats and the simulation of a sense of real-togetherness with people without having to travel. A tele-health VR system has been developed by XR-Health to ease the stress and concern of solitary patients and engage them in both physical and mental exercises.

Table 2
IoMT medical applications.

S.No.	Medical Applications	Ref.
1	I-GCMS-IoMT based Medical Nursing System	[44]
2	AR-IoMT based Smart Rehabilitation System	[25]
3	IoMT based Kidney abnormality detection system using ultrasound imaging	[54]
4	IoMT Application for patient posture recognition using supervised learning	[55]
5	Monitoring patient/ Remote patient monitoring	[5]
6	IoMT Monitoring physiological conditions	[81]
7	Decision making and home-based medical health monitoring system for neurological disabled patients	[45]
8	Autistic patient monitoring medical health care system using IoMT	[20]
9	Smart medical nursing healthcare system for patients	[12]
10	Remotely ECG monitoring system based on IoMT	[69]
11	BAKMP-IoMT: Secured and smart medical healthcare system	[28]
12	EAI-IoMT based smart medical health band to monitor elderly people	[77]
13	I-GCMS based smart Hospital	[87]
14	SpO2: Monitoring of OSA (obstructive sleep apnea) diseased patient by heart rate variability	[38]
15	BACKM-EHA: Mobile electronic medical health care system based on IoMT	[95]
16	IoMT based Inexpensive cardiac arrhythmia management (ICarMa) system for cardiac patients	[48]
17	IoMT based MSSO-ANFIS medical healthcare monitoring system for heart disease prediction	[47]
18	IoMT based Medical Bot Michael for identification of carotid plaque risk factors	[90]
19	IoMT based Ubiquitous medical Healthcare Monitor System (UbiHeld) for Chronic diseased Patient	[60]
20	Secure-iGLU-IoMT based Glucose monitoring	[43]
21	BioSenHealth 1.0-IoMT based Heart-rate monitoring system	[62]
22	Hand hygiene monitoring	[82]
23	Depress-DCNF-IoMT used for Depression and mood monitoring	[51]
24	Parkinson's disease monitoring	[99]

Parallel computing-fog, edge and cloud computing

Parallel processing techniques are the foundation of distributed computing approaches that make use of ideas like distributed systems, virtualization, edge devices, and sophisticated analytics. An increasingly used source of massive data is the IoMT and its real-time interaction-based apps, thus it's critical to recognize and distinguish between the data that must be stored locally and the data that needs be transferred through cloud services [66].

For predicting COVID-19 outspread, prior researchers made an IoMT-based fog-cloud medical system with a four-level architecture that encompassed data collection, data representation, mining and extraction, and prediction and decision modelling. A health-monitoring framework was created by Cui et al. [19] which used cloud computing, IoMT sensors, linked sensors for monitoring heart beat rate, oxygen saturation %, core temperature, and patient eye movement.

5G networking

Fifth generation (5G) networks have evolved as a result of quick developments and adoption of IoMT-based activities (Fig. 8). Recent 5G technologies include new Radio Access Technology (RAT), enhanced antennas, increased frequency utilization, and redesigned infrastructure. In addition to sensors, portable devices, diagnostic supplies, camcorders, and VR/AR, 5G is robust enough to accommodate hundreds of medical devices at once. Teleconsultation, telemedicine, intelligence therapy, and even telemedicine are just a few examples of how developing 5G innovations are being applied for medical purposes [8].

Wong et al. [96] developed a fluorescence sensor that works with 5G for precisely determining the viral spike and nucleo-capsid proteins of COVID-19. They proposed a 5G-based wireless sensor network with a fast three-tier high-security authentication mechanism using biometrics, passwords, and smart cards. This system ensures that time-bound anonymity for multi-server e-health systems is maintained while also significantly reducing network load and database expense.

Big data visualization and analytics (BDVA)

The enormous amounts of information that IoMT devices create must be appropriately handled in order to make informed decisions. Virtualization has developed into a key tool for handling big data by utilizing internet-based storage and sharing of data from anywhere [9]. Concomitantly, edge computing and sensor networks solve the problem of continually growing amounts of data that was being regularly collected from the Internet of Things. To stop epidemics, treat diseases, and predict the effects of sickness, the health industry uses big data analytics. The platform integrates structured, unstructured, or semi-structured data from biosensors as well as information about the surrounding area of the user, and their current position and health. The cloud is used to display the combined data. Prior to transferring the information to doctors or other distant users; the database analytics do analysis of the data by performing mathematical calculations [79].

Block-chain

As is clear, a significant level of data exchange between medical devices and healthcare professionals is essential in intelligent medical practices. This frequently causes data fragmentation, which can leave gaps in transferred information and make it difficult to comprehend, impeding the therapeutic process.

Based on block-chain innovation, researchers have created "Healthcare Data Gateway (HDG)," which allows patients to exchange their data without breaching privacy policies [25]. Using a block-chain architecture and edge infrastructures, Parn and Edwards [68] created "CoviChain" to facilitate the safe transfer of COVID-19 afflicted patients' data to the health service.

Testing and tracing for disease spread

The main focuses of international efforts to prevent illnesses, particularly to stop their spread, have been screening and surveillance. Numerous IoMT-based devices have been employed to test, analyze, and pinpoint the locations of infected individuals in order to track the potential spread of virus infection [3,84]. Few examples of

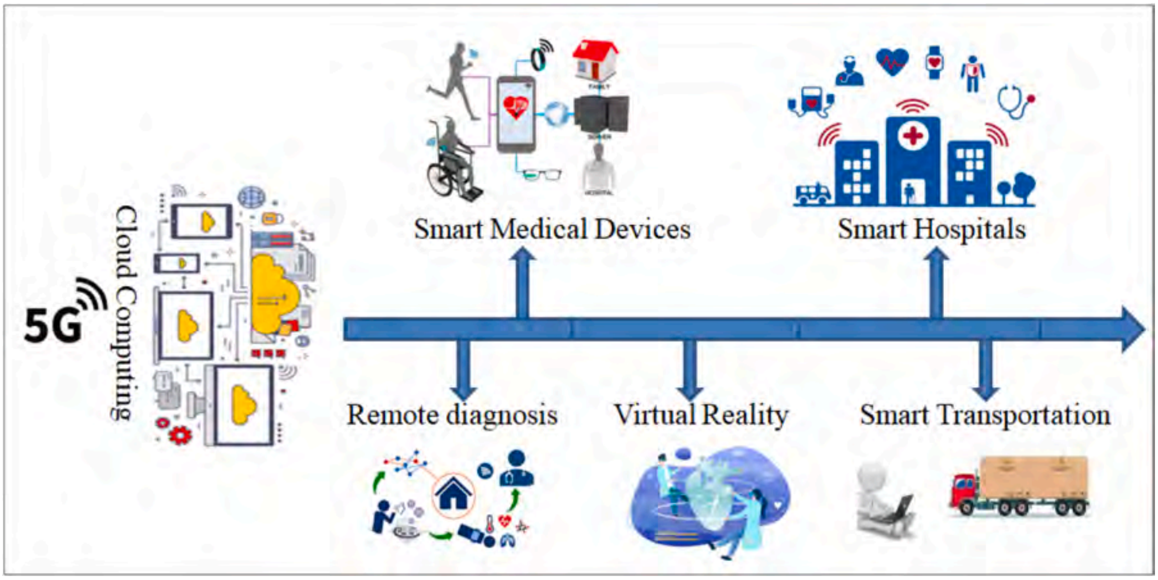

Fig. 8. Schematic representation of applications of 5G in healthcare.

testing and tracing devices used in healthcare which may be aided by IoMT technology include Polymerase Chain Reaction (PCR) Machines, Rapid Antigen Tests: Rapid antigen tests, such as the Abbott BinaxNOW and the BD Veritor System, Molecular Point-of-Care (POC) Devices, Wearable Contact Tracing Devices, Digital Thermometers, Mobile Testing Labs, and Pulse Oximeters. Healthcare professionals may treat infectious illnesses such influenza, yellow fever, influenza A (H1N1), human papilloma virus (HPV), Ebola virus disease (EVD), Zika virus (ZIKV), and coronavirus more successfully by using IoMT-based point-of-care diagnostics (POCT) techniques (COVID-19) [40]. Dense Convolutional Neural Network (DenseNet-121) and Residual Convolutional Neural Network (ResNet-34) were created by Bibi et al. [14], as part of an IoMT-based system for rapid and secure real-time leukemia testing, diagnosis, and therapy. In order to anticipate a person's COVID-19 disease status, widespread usage of multiple IoMT devices were increasingly utilized. In 66% of patients whose RT-PCR result changed from negative to positive within two days, a machine learning model was created to predict initial COVID-19 RT-PCR positivity using the patient's distinctive statistical profile (age, sex, and race). Similar to this, early COVID-19 infection was identified with 94.03% accuracy utilizing chest X-ray, CT, and echocardiography data. Deep learning and pattern recognition approaches, such as convolutional neural networks (CNN) were used. Ahmed et al. [3], examined ResNet152V2, DenseNet201, VGG16, and Inception ResNetV2 as the four transmission methods for the early identification of COVID-19 infection. It was shown that outcomes produced by a group of pre-trained models were more successful than those produced by specific models.

Challenges within smart healthcare systems to be considered during IoMT network design

Before IoMT can be widely employed for clinical purposes, a variety of problems and effects, including data processing, regulation, compatibility, adaptability and upgradeability, and cost effectiveness, must be addressed (Fig. 9). Implementing IoMT systems can involve significant upfront costs, including the development and integration of devices, infrastructure, and connectivity solutions. Healthcare organizations need to carefully assess the cost-benefit ratio of adopting IoMT technologies and ensure that the long-term benefits outweigh the initial investment. IoMT introduces regulatory challenges due to the vast amount of sensitive patient data being generated and transmitted. Compliance with regulations such as HIPAA (Health Insurance Portability and Accountability Act) and GDPR (General Data Protection Regulation) is crucial to protect patient privacy and maintain data security. IoMT systems collect and transmit a wealth of personal health data, making privacy and security paramount. Protecting sensitive patient information from unauthorized access, data breaches, and cyber threats is critical. The interoperability and integration of data from diverse sources pose significant challenges. IoMT systems generate large volumes of data that need to be effectively managed, stored, analyzed, and shared across different healthcare systems and platforms. Many IoMT devices are battery-powered, and their continuous operation and connectivity can drain batteries quickly. Ensuring sufficient battery life and managing power consumption in resource-constrained environments are important considerations for IoMT deployment. The reliability and accuracy of data generated by IoMT devices are crucial for effective healthcare decision-making. Data quality issues, such as noise, biases, and inaccuracies can arise due to device limitations or environmental factors. Data validation techniques, data cleansing algorithms, and quality control measures should be implemented to ensure the accuracy and reliability of IoMT-generated data.

AI is the ability of software or a robot controlled by a computing device to carry out tasks usually done by individuals using their brains. A smart medical system with appropriate data interpretation techniques may also use the implanted or portable sensors on the body of the person under monitoring to assess health status [18]. AI has the potential to enhance user engagement while simultaneously controlling and preventing illnesses in real time [23]. Creating an IoMT-based smart network is extremely challenging due to the aforementioned challenges that influence engineering techniques at every edge. The routing protocol, which also offers information to facilitate packet forwarding across nodes, will regulate the exchange of data between routers. The collection of extremely sensitive patient records in a smart healthcare system using small, low-power IoMT sensors is feasible. Although, the aforementioned problems can't be fixed inside embedded or worn IoMT devices, but they can be fixed by using effective routing design, power-saving techniques, and channel efficacy in protocol and standard development procedures [65].

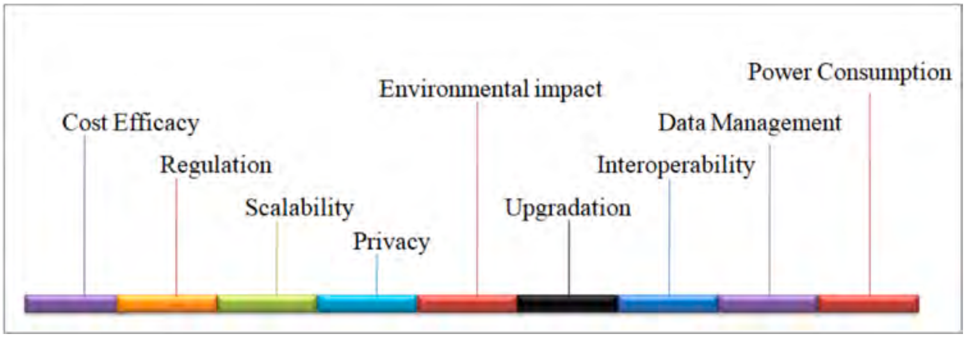

Fig. 9. Challenges of IoMT in the context of Smart Healthcare System.

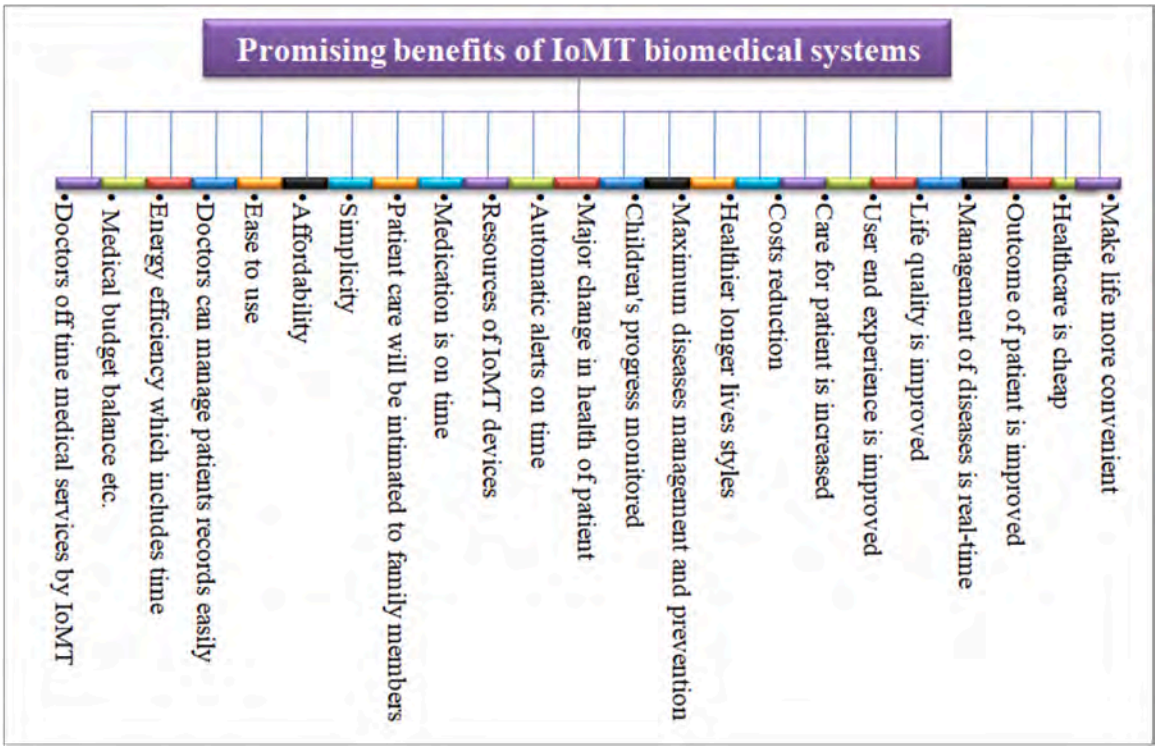

Fig. 10. IoMT applications in the context of remote healthcare management systems.

Benefits of IoMT in biomedical and healthcare systems

IoMT has many rewards for people, society, the environment, consumers, and companies, however there are advantages and disadvantages with any technology. Fig. 10 lists the major benefits that IoMT provides for us, particularly for medical healthcare. The world has become an idealized version of what people hoped it will be in the 1990 s because of IoMT based platforms and apps [24]. As a result of the Internet of Things (IoT), the world of information distribution has experienced fundamental changes. This has considerably aided the growth of many challenging industries, but especially that of medical products. This is a key factor in bridging the gap among medical professionals, patients, and healthcare facilities thanks to its simplicity, precision, and adaptability. IoMT enables medical professionals to perform more efficiently and energetically with less effort and brainpower. Patients have benefited greatly from the adoption of IoMT in the medical domain since it is so simple to use.

IoMT has brought about fundamental shifts in the field of internet access, which has greatly aided the development of many difficult sectors, particularly that of medical items [85]. This is a key factor in bridging the gap between medical professionals, patients, and healthcare facilities thanks to its simplicity, precision, and adaptability. The use of IoMT allows medical professionals to perform more effectively and aggressively with less effort and understanding [31].

IoMT applications are widely employed in healthcare and medicine and cover a wide spectrum of technologies, including cutting-edge robots and drones and big data powered by machine learning [58]. Because of the increase in demand for telemedicine tools and remote monitoring technologies during the pandemic period, authorities and business people have recognized the rising relevance of IoMT in medical services such as medicine delivery by drones to individuals receiving care at home. For instance, in Rwanda, donated blood has been shown to be transported using drones. Patients often prefer the prescriptions their friends recommend over the drugs their doctors provide them on a regular basis. Doctors may efficiently manage the therapeutic process with the use of IoMT healthcare technologies that track patient participation and treatment adherence [58].

The current treatments need a lot of resources and usually don't meet patient expectations. This specifically pertains to Asia, Africa, and Latin America. IoMT technology significantly reduces the cost of offering services like transportation, manpower, and infrastructure maintenance [97]. But integrating IoMT technologies into the medical industry is challenging. The main issues are insufficient privacy laws and the use of antiquated infrastructure. The cost of using IoMT technology has increased recently. However, the right IoMT technology projects may pay off quite quickly.

Conclusion and future prospects

Saudi Arabia is a rapidly developing nation that remains behind other developed nations mostly in terms of 'quality of living' and medical facilities. To overcome this gap, pharmaceutical and biotechnology industries are focusing on the development of novel products and their widespread adoption. Advancements IoMT can now be deployed faster and safely. The health care system has significantly improved as a result of innovations like smart technology and remote health monitoring systems. An overview of IoMT is provided in this review paper, with a focus on the numerous key technologies applied in intelligent healthcare systems. Here, we've covered a variety of approaches, including RFID, AI, blockchain, and other technologies which are employed in intelligent medical practices. The integration of an IoMT network-based intelligent medical system presents a number of key protocol engineering challenges that must be taken into account, including the patient's standard proprioception, fluctuations in the health monitoring device's temperature, the network's energy efficiency, the device's transmission range, IoMT devices' performance in a heterogeneous environment, quality of service, and security. This article evaluates and contrasts several IoMT designs that have been used by multiple authors for intelligence medical practices. A complex medical system can only function perfectly when it gets accurate and trustworthy data. We are providing a detailed check of a number of wearable medical data gathering technologies to assure the accuracy of the medical data acquired. To collect medical data, one may employ wearable and implanted IoMT devices on the patient's body. This article provides a comprehensive evaluation of current efforts made by many authors to maintain the energy efficiency of an IoMT network using both tabular and graphical approaches. Numerous factors must be considered while determining a system's efficiency, including energy demand, packet transmission, service quality, transmission rate, latency, network throughput, etc. We present many logical link solutions in this study for determining accuracy and efficiency in the IoMT-based healthcare system. We also delineate IoMT framework's numerous health areas, such as a list of sensors and how they might be used to assess the health of the individual being evaluated. Given the sensitivity of medical data, a comprehensive review and future improvements must be made to the system's security.

The future aspects of the multirole of IoMT in biomedical systems for managing smart healthcare systems are highly promising. IoMT will enable more advanced and comprehensive remote patient monitoring capabilities. In addition, IoMT combined with machine learning algorithms will enable predictive analytics for identifying high-risk patients and predicting disease progression. One of the challenges in healthcare is the lack of interoperability among different systems and devices. In the future, IoMT will drive the development of standardized protocols and data exchange formats, enabling seamless integration of data from various sources such as EHRs, medical devices, wearables, and healthcare applications. This will result in a comprehensive view of the patient's health and enable more informed decision-making. As IoMT expands, robust cybersecurity and privacy measures will be critical to protect sensitive patient data. Future developments will focus on ensuring data integrity, authentication, encryption, and secure data exchange protocols to safeguard patient privacy and prevent unauthorized access or data breaches. Overall, the future of IoMT in managing smart healthcare systems holds immense potential for improving patient care, enhancing healthcare delivery, and promoting population health. It will transform healthcare from a reactive model to a proactive and personalized approach, leading to better health outcomes and improved quality of life.

In brief, this review article also offers a comparative analysis of various available IoMT architectures integrated for real-time data capture, diagnosis, and monitoring of patients' health conditions. Further, future novel trends of various biomedical domains of IoMT, including sensors analysis with their applications that can be useful in the emergency cases to figured out key challenges faced by smart healthcare providers have been discussed. In the context of biomedical challenges, the benefits of various data collection algorithms and techniques based on AI protocols from review-based literature for maintaining the accuracy of the retrieved data to treat current and innovative diseases have been explored. Considering IoMT humongous utility and future applications in view, it can be concluded that IoMT infrastructure will efficiently evolve with the evolution of medical market.

Funding

Deputyship for Research & Innovation, Ministry of Education, Saudi Arabia, Project Number RUP-3–7.

Declaration of Competing Interest

None

Acknowledgements

The authors extend their appreciation to the Deputyship for Research & Innovation, Ministry of Education in Saudi Arabia, for funding this research work through the project number RUP-3–7. Few sentences of this manuscript were possibly improved using ChatGPT, a language model developed by OpenAI, for text generation and linguistic analysis in this study. ChatGPT is a state-of-the-art natural language processing model based on the GPT-3.5 architecture (OpenAI, 2022).

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