Chapter 1
Application of Cloud and IoT Technologies in Battling the COVID-19 Pandemic

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1.1 Introduction

The fresh severe infectious coronavirus respiratory syndrome called (COVID-19) has caused the greatest global challenge in public health after the pandemic of the influenza outbreak of 1918. Coronavirus disease (COVID-19) transmission has prompted significant changes in the populations' behavior around the globe. The first case of the infection outbreak was discovered in Wuhan, China, in December 2019 and was triggered due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus [1–3]. As reported by the World Health Organization (WHO), there have been 30,949,804 confirmed cases and 959,116 deaths of COVID-19 globally, as of 4:30 pm CEST, 21 September 2020, affecting more than 180 countries, and because of the shocking rise of national spread, WHO proclaimed COVID-19 to be a pandemic. These made different countries' governments take immediate control actions since the nations' public healthcare sectors have been distressed. These include the heavily affected regions' segregation; the cross-border

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activity suspension among nations; the closure of colleges, offices, and public places; and the general population activities' restriction by advising them to remain at home full time. Social life and economics had been significantly affected due to these measures put in place.

The societies face different challenges from education, healthcare, production, supply management, travel, tourism, and service provision under existing circumstances and in the post-COVID-19 environment. By way of instance, the overpopulated number of hospitals and healthcare facilities due to the rapid rise in COVID-19 cases and the failure to provide emergency care to regular patients due to reduced mobility are significant obstacles to the battle of the COVID-19 pandemic in the healthcare industry. Likewise, disruptions and increased resource requirement for physical contact monitoring and limited availability of efficient and automatic contact tracking tools inhibit the spread control behavior [109]. Therefore, it is the multiple parties' responsibility to operate with their maximum ability to monitor the evolving COVID-19 condition, actors such as health employees, government officials, academics, engineers, technology operators, and the wider community. To defend and deal with the post-COVID-19 environment, digitalization and the implementation of telecommunications would be critical. Tools such as big data, 5G communication, Internet of Things (IoT), cloud infrastructure, artificial intelligence (AI), and blockchain play a crucial role in protecting and improving people and societies differently. Technologists and engineers would continue to face obstacles essential to incorporate and appreciate these optimized solutions. Their advantages carry out elaborate findings regarding risk management, resources, cost, scope, and quality.

In most cases, mobile device platforms rely on automated hospital control services that use automated technologies (e.g., ultrasound, MRI, endoscopes, electrocardiograms) and computerized patient information systems (e.g., Picture Archiving and Communication System (PACS), Organized System of Care (OSC), and Electronic Medical Record (EMR). Smart healthcare technology platforms have been created. As such, geographic borders have been overcome by the smart healthcare industry and transformed into digital hospitals aimed at all-inclusive patient care and the quality of high-level medical services. Different, Information and Communication Technology (ICT) medical, and big data innovations are developing various services in the smart healthcare field in conjunction with wearable medical device-based artificial intelligence technology. The paradigm of patient care is moving from hospital-based therapy to customer prevention. For instance, the quantified movements used to track and retain daily personal health information, including the volume of blood glucose, heart rate, electrocardiogram, and nutritional information collected by wearable sensor or healthcare apps, have been distributed. The smart healthcare industry is also widening its deployment to telemedicine, mobile wellness, Electronic Health Record (HER)/EMR/ Personal Health Record (PHR), cellular medical facilities, and targeted therapy through a mix of IoT technologies.

Globally, the coronavirus cases keep on increasing regardless of all measure practices to fight the outbreak. In recent times, IoT has gained a strong position in academia and business studies, particularly in healthcare. The IoT movement is reshaping contemporary healthcare environments by integrating technical, social, and economic viewpoints. It develops from traditional medical systems to more customized medical systems, where patients can be more seamlessly diagnosed, treated, and surveilled. With plentiful technology in fields such as healthcare, entertainment, transportation, retail, business, and emergency services control, wearable body sensor networks have transformed the power to modify our lifestyle. The combination of wireless sensors and sensor networks with simulation and intelligent systems research has resulted in the development of an interdisciplinary definition of ambient intelligence to address the challenges we encounter in our daily lives. Creating a reliable and efficient wearable system for monitoring throughout the COVID-19 outbreak is critical. In COVID-19 situation, an IoT-based cloud computing system can be employed to lower the possible spread of the pandemic using enabled/linked devices aimed at people for early diagnosis, monitoring during social distance, quarantine time, and after recovery.

The IoT healthcare system has become one of the most indispensable parts of human lives. This has dramatically increased the medical information system that brings about big data. Healthcare practitioners are already adopting wearable devices based on the IoT to streamline the diagnosis, monitoring, prediction, and treatment process. The healthcare system that depends on IoT assists individuals and aids their vital everyday life activities. The affordability and user-friendliness of the usage of IoT start revolutionizing healthcare services. In recent times, billions of sensors, devices, and vehicles have been connected through the Internet using IoT technologies. Remote patient monitoring is one such technology common for the diagnosis, treatment, and care of patients. For continuous health tracking, wireless sensor networks can be implemented to augment patients' well-being, make the healthcare system more effective, and respond quickly to emergencies.

In reality, more than a decade ago, the transformations given by the cloud computing paradigm created a rich situation for even deeper variations [4]. Data quickly became the most valuable commodity, with algorithms in AI and data science enabling new insights about practically everything. Also, the development of hardware has resulted in various autonomous and interconnected devices' growth [5, 6], giving birth to the age of the Internet of Things [7]. Ultimately, emerging technologies and paradigms support systematic and successful critical decision-making, impacting the industry, sports, research, and even how urban emergencies are identified. Increasing life expectancy levels have left many developing countries with an aging population in need of medical treatment at a period when personnel (healthcare staff, community care, and financial services) are being stretched to satisfy this rising need. This circumstance has driven many health providers to pursue more innovative and cost-effective solutions to address this increasing dilemma. Cloud infrastructure can create some of the technologies required to resolve these issues [8].

Hence, it is possible to take advantage of the latest technical arsenal to build a new wave of smart cities that would forecast epidemic occurrences more accurately, supporting their claim. It's not quick, and as cities become more and more integrated, many problems will still arise. However, the adverse effects of the COVID-19 illness can give this process the requisite improvement. The optimal identification of possible eruptions would take advantage of retrieved data from various sources. In reality, cities and their local and international supply chains, travel networks, airports, and communities, which may be causes of contagion, are constrained by this overall problem. In such situations, to provide comprehensive data, sensor locations, public agent networks, social media, and even individual devices should be incorporated [9]. Therefore, this paper discusses the applications, challenges, and solutions of cloud computing and IoT in battling the COVID-19 pandemic. The article also proposes a framework of an intelligent cloud-IoT-based healthcare system for monitoring COVID-19 patients.

The paper is structured as follows: Section 2 describes the applications of IoT to combat the COVID-19 outbreak. Section 3 addresses the significance of the cloud in fighting COVID-19. Section 4 describes the challenges of IoT-based and cloud computing technologies for fighting the COVID-19 outbreak. Section 5 presents the framework of an intelligent cloud-IoT-based monitoring system for combating the COVID-19 pandemic, while Sect. 6 discusses the practical applicability of the proposed framework. Finally, Section 7 concludes the paper and discusses future work.

1.2 Applications of Internet of Things in Battling the COVID-19 Pandemic

The healthcare system in developing nations is fast changing as life expectancy increased considerably throughout the 1990s [10]. Infectious illnesses are also placing increasing pressure on healthcare systems in these countries [11]. During the twentieth century, life expectancy in advanced countries increased by around 35%. As a result, the number of elderly people is fast increasing [10]. In addition, the spread of chronic diseases has put strain on healthcare systems in some nations due to a lack of financing [11]. As health systems deal with a wide range of symptoms and treatment options, rising infectious diseases and an aging population pose substantial obstacles. Despite the growing patient population, successful techniques have demonstrated in-house telemedicine services to avoid overburdening health infrastructure and lower healthcare expenses [12].

During the COVID-19 outbreak, digital telehealth plays a critical role. Patients communicate with doctors through a portal, and therapy is delivered remotely. The advantage of using a secure IoT system in COVID-19 is that the physicians do not examine the patients personally, preventing the virus from spreading [13]. In this moment of crisis, many countries have begun to use digital telemedicine. Patients receive IoT-based healthcare devices from HealthArc [14], and their data is regularly monitored by medical staff. The data is analyzed, and patients receive recommendations and medicines via their mobile phones or tablets. Among the main telehealth service providers are ContinuousCare [15] and Health net connect [16]. A person with COVID-19 symptoms can use a digital platform assessment tool, such as the "COVID-19 Gov PK" smartphone app [17], which is viewed remotely by physicians. Patients are guided in a timely manner, and this instrument has the potential to save many lives. It also minimizes the number of hospitalizations, readmissions, and the number of patients in hospitals, all of which assist COVID-19 patients to have a better quality of life and receive prompt treatment.

Ambulance medical personnel are frequently confronted with high-pressure, error-prone circumstances [18]. During the present COVID-19 epidemic, the situation for medical personnel dealing with COVID-19 patients has become even more tight and stressful. Remote medical specialists propose required steps to the medical team dealing with the patient in the ambulance using IoT-based ambulances, which is an effective option. As a result, the patient receives prompt attention and is effectively managed. The equipment that uses radio-frequency identification (RFID) is linked to a wireless local area network (WLAN). The relevant medical staff has remote access to the patient's information.

Telemedicine platforms are quite diverse, and most are built to address a single therapeutic goal, such as mobile heart monitoring and stroke rehabilitation [12]. This feature of telehealth systems makes them cost-effective and overburdens health institutions, but it also shows a weakness when patient numbers and disease types grow. The Internet of Things is capable of meeting the demand for more genericity and reliability. To be sure, the Internet of Things combines traditional medical equipment's efficiency and security with the traditional capacity for dynamics, genericity, and IoT scalability. It has the ability to solve the aging problem and terminal illnesses by handling millions of sensors and being broad enough to cope with multiple diseases that require exact diversified checking and action parameters.

The use of IoT in the field of transmissible disease epidemiology is still developing. Nonetheless, the pervasiveness of smart technology, as well as the increased dangers of transmittable disease brought about by global integration and global interconnectedness, necessitates its application in anticipating, preventing, and monitoring COVID-19 pandemics [19]. In several countries [19], web-based monitoring tools and disease intelligence tactics have lately appeared to promote risk management and early detection of epidemics. Despite this, there is a dearth of systematic application of accessible technology. Local health authorities would be able to increase efforts to diagnose, control, and avoid contagious diseases by using IoT-implemented medical care surveillance in a global healthcare system [20].

Using travel data, it may quickly diagnose infectious patients and correctly forecast the spread of an illness to other locations. Essentially, rather than locking down major cities, borders, and enterprises, an IoT-based observation network may aid in the rebuilding of an epidemic and the restoration of the source nation's economies. By including numerous facilities, apps, third-party APIs, and non-health-related mobile sensors, mobile connection in the context of mobile health (mhealth) will boost the efficiency of a medical care network [21]. Medical and security services observing operations, such as wearable IoT, provide for real-time safety monitoring and global health trends. Due to the near impossibility of tracking these enormous geographic regions or groups [22], such advances could close gaps in current monitoring methods. Such methods have been used in computer science and healthcare analysis, but they are relatively new in the epidemiology of transmittable diseases [23]. Despite the current global situation, smart sickness detection techniques based on the Internet of Things can considerably progress current pandemic response efforts.

IoT can minimize the spread of disease by simply gathering and reviewing previously collected data for a lot of the technology currently in place (i.e., Android phones, wearable devices, and Internet connectivity). The collective responsibility of IoT and connected emerging types of machinery could influence the first detection of outbursts and deter the circulation of COVID-19 if the data was enhanced and used. Smart IoT-based disease detection systems will include continuous communicating and recording, end-to-end networking and availability, data variety and review, tracing, and warnings, including choices for inaccessible healthcare support in China and other impacted countries to diagnose and control COVID-19 outbreaks. The heart of the IoT is an Internet-based network that grows and extends; the user side can be extended, thus enhancing the sharing of knowledge and contact between "people." IoT is the science of intelligent detection, location, tracking, and AI services for COVID-19 patients using RFID, Global Positioning Systems, various sensing instruments, information exchange, and community services. If we can go deeper into its work, it will undoubtedly yield unpredictable results.

RFID readers can be mounted on robots in the therapeutic work of stopping severe acute respiratory infections (SARIs), and UHF stickers can be read when a drug is inserted into the device to validate the delivery of drugs. This clinical program has gained valuable expertise. When a robot triggers its RFID reader, it can collect the necessary information and quantities of all the medications in a cabinet. A prescription can be delivered to the medical units correctly by precisely matching the drug information. In Danville, Pennsylvania, the United States, the Geisinger Medical Center has implemented integrated RFID robotics to guarantee that a drug is reliably administered to all operation units, with images sent immediately.

RFID technology can also be used to create a medical waste management network that can effectively control and track all COVID-19 medical waste processes, including generation, recycling, transportation, and treatment. Managing suspected patients is a complex problem. The explanation is that it is only possible to recognize those with fever or who've fallen sick. The other potential virus carriers aren't isolated and are the next wave of infection. Tell them to live in their own homes or to remain in the neighborhood to minimize personal transition. The recommendations suggest self-protection by ensuring good hand and mouth health, keeping healthy eating habits, and avoiding direct contact with those with respiratory illness symptoms (such as coughing and sneezing).

Nevertheless, this policy's impact is not understood, so there is little quality assurance. Therefore, there is an immediate need that IoT be implemented to handle this group of patients better. Compared to conventional medicine, IoT will track the suspicious patients' clinical and medical status during the process, illustrating the management benefits of offering customized treatment strategies for various individuals' classes. By utilizing wireless radar gadgets and modern IT, patients will benefit from medical services, thereby guaranteeing suspicious patients' health and preventing their relatives' infection. The expanded health-specific edition of the IoT [24] is applied to the present situation. It should build a digital forum to help people access sufficient treatment at home and establish a robust network for policy and community organizations.

Persons with minor symptoms may receive treatment and healthcare supplies (protective gloves, thermometers, drugs, POC COVID-19 supplies for treatment, and infection control). Inmates may upload their medical position to the IoT (medical cloud storing) portal online daily and pass their records to regional clinics, the

Centers for Disease Control and Prevention (CDC), and state and resident medical offices. Infirmaries might then suggest operational wellness sessions built on each patient's medical status. The régime (the CDC local and national medical offices) may distribute resources and establish isolation places (guesthouses or consolidated isolation amenities) appropriately. This will minimize national health expenses, alleviate the pressures of medical equipment shortages, and deliver a centralized framework that would tolerate the régime to track infection transmission effectively, administer materials efficiently, and enforce response strategies. Figure 1.1 displayed prospective applications of IoT to fight the COVID-19 pandemic.

Personal and clinical IoT-assisted equipment are divided into two categories [25]. These devices keep track of the user's heartbeat, exercise, sleep, nutrition, and weight. These are beneficial in the fight against COVID-19 because rest and sleep are important elements for patients with this condition. Sleeping well boosts the body's immune system's ability to combat the virus [26]. On the portals given by these gadget producers, the patient can view his reports and, if necessary, provide information to the relevant physicians. If particular algorithms are integrated into existing devices, IoT-based wearable gadgets can help to prevent the spread of coronavirus. Wearable gadgets send out real-time alerts if:

- The social distancing procedure has been broken.
- There is a COVID-19 patient in the neighborhood.
- The government has labeled the area a danger zone due to the coronavirus outbreak.

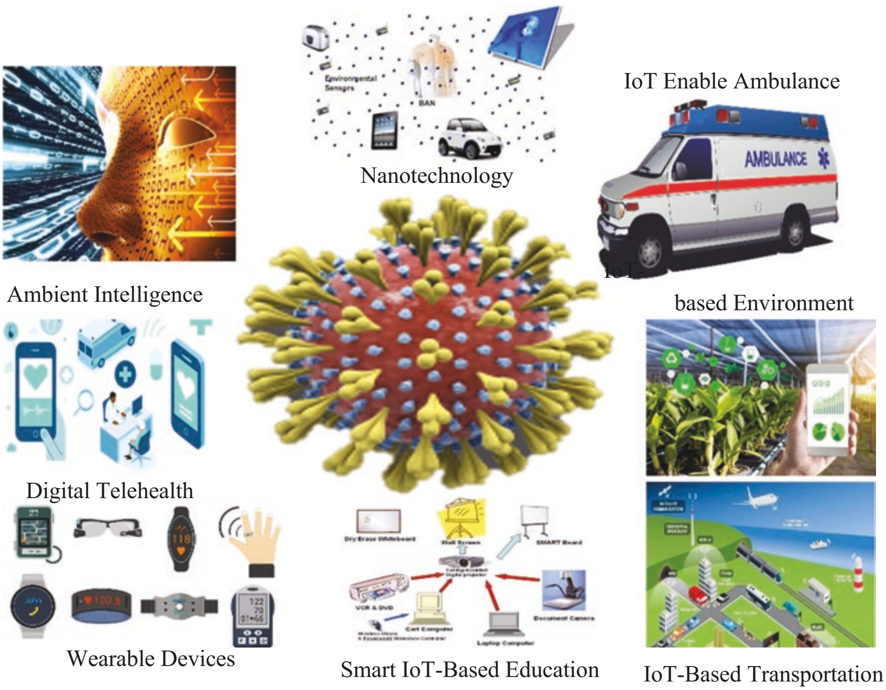

Fig. 1.1 Prospective applications of IoT to combat COVID-19

Many countries have installed autonomous human body temperature-sensing machines, which include a camera that is integrated with the sensor and delivers real-time data to a server. The system also uses artificial intelligence to recognize a face and compare it to a central database [27]. The usage of these gadgets aids in the tracking of COVID-19 patients. Enabling smart infrastructure that senses the environment and generates real-time reports for law enforcement agencies enforces social distancing [27]. Sensor data is continuously saved on an Internet database for continuous monitoring [28]. Hazardous gas or carbon content is reported to the environmental protection agency and updated on a server that may be accessed online [29]. Researchers are currently working on detecting the coronavirus, which can be used in the same way. Smart infrastructure solutions are provided by IBM, Microsoft, Huawei, and Cisco, among others [30].

Ideally, engineers and technicians would avoid warehouses, isolated locations, or busy places in travelling and visiting because they fear of being infected with the virus. Nevertheless, their physical appearance on site is needed because they can't get away with manually operating the equipment available. By using special sensors mounted in machinery and enhanced knowledge, real-world overlays, and remote expert feedback, IoT may help solve their repair problems and conduct machine operation remotely. AI may also anticipate when machines need repair (predictive maintenance) or when they might be faced with a challenge. In this way, physical visits will be significantly decreased, helping to safeguard workers' health and welfare, thus enhancing efficiencies at the facilities' level of service. When supermarkets continue imposing limits on sales of goods per customer, IoT and AI have also produced future alternatives. Smart shelves, smart fridges, video analytics, and an end-to-end integrated supply chain will help retailers deal with planning challenges and even reduce customers' extreme behavior due to hysteria.

A couple of years ago, a major US retail chain put IoT trackers in its trolleys to prevent daily theft. Perhaps it is time to start applying this to the store shelves of significant homes, sanitizers, and everything else that is already overselling in an attempt to control supplies and prevent hoarding behavior properly. Smartwatches and fitness trackers will be readily available in the not-too-distant future, and people with chronic conditions will be able to record temperature, asthma, and heartbeat without the use of intrusive instruments. For this fact, patients will be able to transmit real-time and past data to public or private hospitals anytime they feel unwell so that medical health IT departments will interact with patients' wearables and mobile devices. In this way, the treatment of coronavirus or other diseases may be prepared even more effectively and with minimal resources expended optimally. Smart connected medical devices, such as smart home ventilators, together with video and wearables, may support patients' monitoring at home, give updates to those in distress, or even alert when paramedics are required to come and move them to the hospital.

Ventilators are essential in treating people that have become contaminated. The health services have not been prepared to deal with this magnitude of a pandemic, and a resulting shortage is now widespread in only the most developed hospitals. An IoT 3D printing may be a lifesaver in the face of coronavirus-induced supply shortages, with an IoT 3D printer that offers critical medical equipment, for example, replacement valves. An Italian company called Isinnova does this, taking a 3D printer to a Milan hospital and manufacturing incomplete valves to be shipped to a hospital in Brescia, Northern Italy. Touch screens have been the chosen user interface (UI) until recently: tablets, computers, and even doors. Nonetheless, coronavirus being more quickly transmitted from a contaminated surface than by air has made direct contact sound risky. Many UIs that don't need any physical contact are also usable. Voice has already triumphed over tactile user interfaces, primarily through smart speakers and digital helpers. Despite people confining themselves inside the building, there will be increased interest in smart home apps and smart speakers' voice apps. Another functionality that gains ground in smartphones is beyond speech, biometrics, and their use for eye/face identification, such as facial picture identification to open phones or make payments. The most extensive penetration is in China, but the opportunity for the remaining part of the biosphere is enormous. Wearables, for instance, smart payment watches and other use cases (enabled by voice or close contact), can allow us to escape physical surface contact.

These technologies are now being implemented in major cities to reduce the pandemic. For example, for simultaneous tracking of COVID-19 inmates, the Shanghai Public Health Clinical Center utilizes physique fever monitors laterally utilizing facts transferred directly to the nurse post, thus minimizing possible sensitivity to healthcare workers [31]. Similarly, a device now used for medical interviews with sensors was installed in Boston to assess patients' breathing degree and physique fever. In Singapore, a contact-tracing mobile program utilizes Bluetooth wireless technologies to identify individuals similar to COVID-19 patients [32, 33]. Apple and Google are working on touch monitoring and detection software that will be made available to many countries worldwide that are intended to significantly step up the recognition that warns users who have been naively near to COVID-19 inmates. IoT won't solitarily combat the present pandemic but could also be used to deter potential outbreaks.

1.3 Applications of Cloud Computing in Fighting COVID-19 Pandemic

Cloud computing will play an essential part in absorbing healthcare transformation expenses, optimizing assets, and bringing the new age of technology to life. Emerging policies are targeted at obtaining data at any time and anywhere that can be achieved by transferring health data to the cloud. This contemporary distribution model will make healthcare more productive and operational and lower innovation expenditures [34]. Still, it also presents some obstacles due to issues regarding the security of sensitive health information and compliance with a specific criterion such as HIPAA. Healthcare providers, taking into account these security and privacy concerns, can unquestionably reap the benefits of cloud computing technologies and provide substantial benefits, such as expanding the eminence of service for patients and reducing healthcare spending [8].

Cloud computing's critical features are (1) self-service on demand, (2) wide grid access, (3) resource sharing with other occupants, (4) swift elasticity, and (5) calculated facilities. In complex resources, clouds offer benefits such as processing energy or storage abilities, universal access to resources from anywhere at any time, and high resource versatility and scalability. In several business fields, these advantages have been the purpose for the growing acceptance of cloud computing. This principle has also evidently been adopted in the area of healthcare in recent years. At least in the mainstream literature, it is provided by healthcare IT firms. Still, even in the systematic past, work done on cloud computing for healthcare applications is gaining interest; a continuously growing number of papers and books appear.

The capacity to share data between different systems would be one of the main advantages of cloud computing. This capacity is something that IT urgently needs for healthcare. For example, cloud computing can enable healthcare professionals to share data such as EHR, doctor's references, medications, insurance data, and research reports stored via various information systems. This is already happening in the radiological market. Many organizations have switched to the cloud to minimize their computing costs and promote the sharing of pictures [35]. Cloud computing has provided clinics, hospitals, insurance providers, pharmacies, and other healthcare companies the ability to agree to cooperate and exchange healthcare data to provide improved service quality and minimize costs. Looking at the industry developments, it seems that once all the obstacles it presents are resolved, cloud-based schemes will eventually turn out to be the standard in healthcare.

The healthcare system's ecosystem, which comprises health insurance providers, hospital and physician networks, laboratories, clinics, patients, and other institutions, is vast, diverse, and highly nuanced [36]. And all of these must operate under many government regulations [37]. Any sensitive details must be exchanged confidentially and safely between these agencies quickly and accurately to function efficiently and rapidly in this ecosystem. In the healthcare sector, protecting the patient's data is very sensitive to privacy issues. Possibly one of the reasons why the development of healthcare moving into the cloud has created negatively affected on medical privacy and security. Innovative technology and resources must be managed when it comes to cloud sharing. However, as they theoretically range between cities, states, and even nations, there are many other records, knowledge, and resources that can benefit from collaboration by cloud usage.

Private clouds tend to be deployed first because of security issues in the current scenario and then shift into public networks [36]. It may be a good idea to first set out the healthcare industry's top priorities and then analyze which cloud computing elements can be efficiently implemented to support them. The efficiency of services provided to patients and customers, privacy, data security and integrity, and catastrophe recovery seems to be at the forefront of today's rising global healthcare costs [37, 38]. Some of the inherent features can be leveraged to meet some of these objectives, such as flexible architecture, data centers for the provision of permanent data, protection models, and rapid access to information.

Cloud computing encourages IT facilities that are accessible from all locations and at all times [39]. It is a new mechanism, not a new technology, to deliver computing services [40]. Examples of nonmedical cloud services are Microsoft Office 365 and Google Docs, while examples of medical service apps are Microsoft HealthVault and Google Health platforms [41]. Compared to traditional computing, there are three significant enhancements provided by the cloud computing model: (1) computationally intensive solutions that are accessible on request, (2) service delivery without charge – customer upfront commitment requirements, and (3) flexibility for short-term use [42]. The cloud model has influenced many sectors, and it is estimated that approximately 80% of today's businesses will have embraced cloud computing by 2020 [35]. Companies that lack capital and infrastructure should also implement cloud computing to set up on-site applications [43]. Cloud computing, especially within the electronic health records (EHRs) field, transforms healthcare IT [44]. Cost minimization in IT investments will contribute to improved healthcare facilities [45–47]. It is estimated that drug costs can be decreased by 80%, and payment can be done within 2 hours for patients and insurance providers than up to 7 days with an implementation.

A cloud-based framework has been suggested to dynamically compute patient records with sensors attached to medical equipment to process data for collection, accessibility, and distribution. During the COVID-19 pandemic, this device can manually reduce typical errors or data collection errors manually [48, 49], not just simplifying the procedure but also increasing access to high-quality data [50]. By combining the ambulance services with patient records, the Greek National Health Service has built an emergency care program in the cloud, ensuring direct access for doctors while being willing to use all resources while maintaining low costs as much as possible [51].

In Australia, a partnership between Telstra and the Royal Australian College of General Practitioners (RACGP) suggested an e-health cloud [35]. This collaboration aims to develop diagnostic and response to medical software, medications, and training and referral facilities. Cloud processing technologies have provided successful support for bioinformatics research in the medical field [35, 52–55]. Although cloud computing has several value-added ideas driven by a novel paradigm of IT service distribution over the network, economic benefits appear to be the most significant factor in its popularity and widespread acceptance.

Lowering the cost of healthcare delivery is a significant catalyst for the implementation of cloud technology in healthcare. This expense has risen to such immense proportions that governments are facing severe problems with funding. The realization that patient care can be enhanced by technology while lowering costs has ensured that policymakers can drive the historically sluggish healthcare sector to a faster adoption rate. Big data development in healthcare is another significant factor [56, 57]. When the quantity of digital information grows, the capacity to manage this information is becoming an increasing challenge. This knowledge embraces the keys to future clinical developments but is also inaccessible to scientists. Cloud computing can be the supporting reason for large-scale knowledge exchange and convergence [58]. The paper [59] addresses high-performance computing (HPC) bioinformatics solutions, big data analysis paradigms for computational biology, and the challenges that are still accessible in the fields of healthcare.

In particular, the authors pointed out that, thanks to virtualization that prevents transferring too much big data, cloud computing solves big data management and analysis problems in many healthcare fields. Also, in the particular area of telemedicine, it is critical to have an infrastructure to support high-throughput, high-storage capacity and safe connectivity to allow effective management and automatic analysis of broader patient populations. Cloud computing can fulfil two criteria of horizontal scalability (i.e., the ability of a device to extend its resource pool for managing heavy loads efficiently) and spatial usability (i.e., capacity to retain performance, usefulness, or usefulness independent of local area concentration advancement to a more dispersed geographic pattern) [58]. In the medical imaging region, the amount of data can exceed petabytes thanks to high-resolution imaging instruments. It is also apparent that the cloud computing paradigm will render a significant benefit to addressing the computational needs relevant to medical image reconstruction and processing and facilitate the extensive exchange of digital images and also advanced control processing.

Cloud computing is a new and progressively evolving field of healthcare improvement. In combination with a pay-per-use model, universal, on-demand access to nearly limitless resources allows for new ways of creating, providing, and utilizing services. In an "omics setting," cloud computing is also used in genomics, proteomics, and molecular medicine computing. Medicine is a collaborative and highly data-intensive endeavor [60]. Advances in the omics fields produce large quantities of data to be processed and stored (genomics, proteomics, and the like).

The subordinate use of medical data with text or data mining techniques also implies an increasing request for complex, accessible services. These tools are also solitarily temporarily used so that stable infrastructure projects are challenging to justify and, alternatively, flexible on-demand services are pursued. Cloud computing seems to be a feasible alternative to meet these demands. Commercial providers such as Amazon and Microsoft pledge to make available hundreds of virtual machines at their fingertips, almost instantly, and only they're just wanted for the moment. The benefit of such deals is that they only have to be paid for the setup, scale, and period they are essentially used during these services.

Enormous medical costs and the maintenance of big data during the COVID-19 outbreak require technical advances so that at any time and everywhere, everybody has access to healthcare services. The development of technology has allowed telehealth to provide online healthcare facilities. For COVID-19 patients not permitted to travel, for villages in rural zones, and for individuals who do not have access to medical care, remote facilities help. Telemedicine uses include the transmission and storage of medical images, video conference patient counselling, continuing education, and facilities in the electronic healthcare field. Sadly, the use of telemedicine technology is hindered by technical and financial costs [61]. Studies have given cloud computing that offers, among other things, remote support capability; accessible, transparent resources; efficient, extensive Internet connectivity; scalable and resource pooling; robust medical data sharing and processing; and the sharing of big data patient records.

Many studies have found that inadequate patient information access explains most medical errors, especially during the COVID-19 pandemic [62]. The cloud-based medical system has been regarded as a possible system to increase openness and reduce the extent of medical errors during the COVID-19 period to correct health data [63, 64]. Many medical organizations have also chosen cloud storage to obtain and store comprehensive patient data and maintain their electronic health record systems. Electronic health records have evolved rapidly over the last decade, providing a gorgeous basis for data mining to recognize designs and styles in the big data industry in healthcare. Another common point for exchanging medical data is the interchange of electronic health records. By communicating a standard hub, these businesses facilitate healthcare sectors to transmit information rather than maintaining ties with many peer businesses [65].

Cloud computing also offers secure storage and sharing resources that can reduce local traffic to make organizations agile [66]. Lowering the cost needed for starting up automated medical records, which is lacking in many healthcare segment facilities, will improve the healthcare sector's efficiency [67]. During the COVID-19 pandemic, prescriptions and diagnoses, for instance, can be shared through the cloud over different systems. Therefore, for service enhancement and higher standards, hospitals and doctors exchange patient records. Electronic health record cloud storage's primary advantages are the capacity to exchange patient records with other specialists at home and overseas, the facility to pool data in one location, and the ability to access files anytime and anywhere. Electronic health record cloud computing enables patients to view, replicate, and transfer their secure health records [68]. Regardless of cloud computing influences to capture and store extensive health data, the prime problem is the failure of the network, protection, and privacy of patient information that users, hackers, malware, and so on are exploiting [69, 70].

Figure 1.2 displayed the applicability of cloud computing in fighting the COVID-19 pandemic. There is an increasing influx of people to urban areas today. Healthcare facilities are among the most critical characteristics that affect people arriving in city centers during the COVID-19 outbreak. Metropolises are therefore financing a digital transition to offer residents healthy environments [71]. On the other hand, because of its vast number, high speed, and remarkable variety, conventional models and methods for full conservational performance assessment are threatened by the advent of big data [72]. Also, because of their carbon emissions, traditional Information and Communication Technology (ICT) systems damage the atmosphere [73]. On the other hand, cloud services are a cost-effective medium for accommodating large-scale infrastructure systems that have gained considerable acceptance [31]. Therefore, the use of cloud computing is a significant phase in the green processing process that saves resources and protects the atmosphere. The use of sufficient equipment and cloud space saves the organization's resources and eliminates the costs of cooling systems, computers, and central servers. Nevertheless, cloud computing supports renewable computing with energy savings, rendering dangerous articles less harmful [74].

By using intelligent mobile computers, cloud computing has inspired healthcare specialists to observe patients' well-being at home remotely [75]. Also, IoT will build a network by leveraging integrated sensors to track the patient's real-time health status and control the treatment process. The IoT would also play an essential

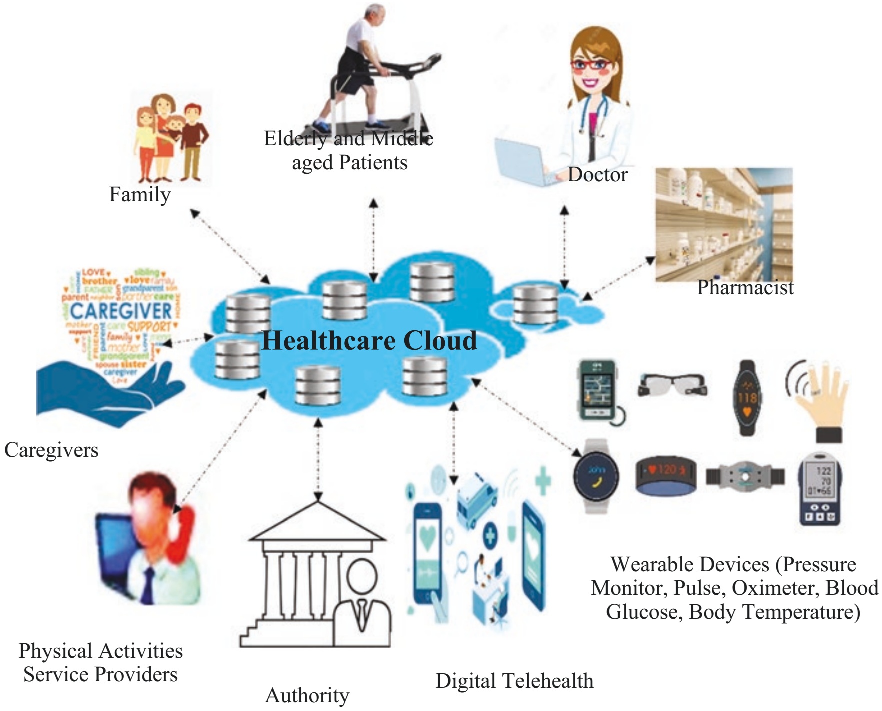

Fig. 1.2 Applications of cloud to battle the COVID-19 pandemic

role in the development of healthcare for the next generation. Although health monitoring systems for IoT-based patients are popular, observing them in outdoor hospital requirements increases the IoT's cloud computing capabilities for handling and storing health data [76].

1.4 Challenges of IoT-Based and Cloud Computing Technology in Fighting the COVID-19 Pandemic

The primary issue in using the Internet of Things in the current disease outbreak crisis of COVID-19 is the protection and safety of the data collected, special and crucial from the patient health perspective. The second problem involves taking precautions when implementing the data connection between the systems and protocols concerned. If the volume and variety of smart sensors that are integrated into IoT networks increase, the possible security hazard also increases. While IoT increases businesses' competitiveness and increases community life quality, IoT would also raise the potential attack surfaces for hacking and other cyber fraud. Hewlett Packard (2014) showed that 70% of the most widely deployed IoT systems contain significant defects. IoT systems have flaws caused by lack of transport encryption, unsafe network interfaces, computer security failure, and lack of authorization. On average, each computer contained 25 holes or the chance of breaching the network connection.

Usually, IoT computers aren't using data encryption methods. Any IoT technologies support critical utilities and strategic resources, like the smart grid and service security. Other IoT technologies will progressively produce large volumes of personal information on household, well-being, and financial situation that companies will exploit for their organizations. The failure of protection and privacy would build opposition to the IoT's acceptance by businesses and individuals. Security issues can be overcome by educating developers to integrate security technologies (e.g., intrusion detection mechanisms, firewalls) into applications and enabling consumers to use IoT security mechanisms installed into their smartphones.

IoT devices can offer a wide variety of IoT users' location and activity details, health status, and buying habits, which can give an upswing to main secrecy concerns as has been the practice for smart healthcare facilities and smart car rescue services. Protection of confidentiality is also counterproductive to facility providers in this case, as IoT-generated data is essential to enhancing people's health outcomes and reducing service providers' costs and improve efficiency processes. The IoT is necessary to promote people's standard of living. According to the 2014 TRUSTe Internet of Things Privacy Index, only 22% of cloud users believe that smart technology's advantages surpass any security issues [77, 78]. Although IoT began to build traction across smart home platforms and wearable devices, trust and adoption of IoT would rely on maintaining individuals' privacy.

IoT innovations (e.g., processors, sensors, cellular technologies) are emerging in an ultra-development period that is significantly longer than the traditional commercial product innovation process. There are already competing requirements, weak protection, privacy concerns, dynamic interactions, and an increasing range of poorly tested products. If not correctly built, multipurpose gadgets and interactive apps will turn our lives into confusion. In an unconnected universe, a minor mistake or failure may not pull down the system. Still, in a hyper-connected environment, a failure in one aspect of the system will cause disarray across the system. Smart home software and medical care and control module consist of integrated sensors, communication equipment, and regulators.

If the sensor of a medical surveillance and control device breaks down, the operator may obtain an erroneous response, which may turn lethal to the customer. It's not hard to picture smart home packages like thermostats and household power meters breaking down or malware attacking, causing unforeseen safety issues. Network connectivity can be overwhelmed with proliferating computer data traffic, causing system-wide latency issues. A single computer could have an irrelevant concern, but other linked devices' chain reactions may be catastrophic for the network as a whole. To avoid confusion in the hyper-connected IoT environment, companies need to make every attempt to reduce the sophistication of connected networks, increase the reliability and quality control of software, and ensure users' protection and privacy everywhere and anywhere on any platform.

The recent wave of digitizing patient records has contributed to a paradigm change in the healthcare sector. The sector is seeing a growth in the amount of data in terms of sophistication and heterogeneity. Big technology is emerging as a possible option with the potential to change the healthcare system. A paradigm change from reactive to positive healthcare will lead to a substantial reduction in medical expenses and potentially stimulate economic growth. As the health sector wields most big data, protection and privacy problems are becoming extremely valuable as new threats and vulnerabilities develop. Privacy and data protection should be thoroughly researched when dealing with health surveillance. Developers can help incorporate protection into computers, software, and programs [79]. As far as data exchange is concerned, designers should use a client-server model wherein the server transfers a certain sort of information with customers while holding other information covered by sufficient certificate [80].

With the emergence of these innovations, data protection has become a growing issue, primarily about the associated risks and misappropriation. A new field of information technology has arisen, called modern ethics [81]. This division of morals is the research of ethical issues related to data and knowledge, algorithms, and associated practices and infrastructures, defined in depth elsewhere [81]. Hospital and immigration must now be prepared to exchange vital statistics, such as data on a spike in the number of individuals with severe fever and individuals coming into or out of the country to the IoT system so that they can be tracked in real time. Also, all relevant systems, in particular edge servers and cloud networks with a 5G network, need to be deployed to ensure quick connection to all devices accessible by computer machines and the various layers of end users.

A more thorough analysis of the use of IoT in monitoring needs to be discussed and a more in-depth insight at the privacy issues that it poses. Event-based IoT detection gathers and transfers direct data from a wide variety of informal outlets (news stories, social media messages, Internet queries) to identify imminent outbreak incidents that propagate quicker than conventional, more restrictive approaches [82, 83]. This has contributed to advancements in infectious disease modelling and bacterium detection and diagnosis (immediate molecular recognition of microorganisms) [82, 83]. The deployment of robotics for this disease outbreak, racism, and secrecy is a crucial concern in using bots during the COVID-19 outbreak. The risk of making the wrong choice between clinicians and protecting the vast data gathered must be considered [84]. IoT is the innovation framework most probably to be used to handle the outbreak. Clinicians may use its facilities to detect their symptoms. It also tracks human health conditions. Most notably, it controls the diagnosis of cases by tracking the position of patients. Protection of collected data is the most critical problem with IoT deployment since data is distinct from one individual to another [85].

Getting a smart city can be immensely helpful in the battle against this disease outbreak by cooperation between healthcare facilities, communities, and various others [86]. The deployment of IoT-enabled smart city is among the most critical ways to react to the current epidemic. The IoT implementations mentioned above [87] highlight the significance of the smart city infrastructure idea as the globe is dealing with the COVID-19 outbreak. Data collection from smart sensors in IoT networks and the deployment of AI deployed at various locations (mostly airports and marketplaces) will help to tackle the present and future disease outbreak. Database distribution and method standardization will contribute to security and privacy concerns that need to be handled using acceptable protocols [88]. In short, the more smart city infrastructure interacts, the more easily the community can cope with such disease outbreaks [87]. Smart city technology will also help residents manage social distances by introducing transit system innovations, like crowd control, smart parking, and traffic redirecting [89].

Security issues, because the government has access to all the data needed to track the outbreak, is a key problem. In the long run, once the epidemic is over, what will be made with the data gathered from humans [90] must be decided. Since safety is the most significant thing for IoT devices to collect user data, considering paying officials may be essential for humans to enable the officials to control their details. Further studies on the use of IoT devices to provide reliable facts to avoid false news should be undertaken. They add to people's tension during an outbreak. Regarding the lockdown process, one of the biggest issues with self-quarantine is that the rate of respiration will deteriorate rapidly. Certain wearable systems introduced could be used for this function. For instance, chest braces with strain gauge sensors [31, 91], face masks with moisture sensors [92], and versatile patches with strain sensors [93] can be allocated for quarantine breathing surveillance. This innovation's reliability differs across smart devices, but it still has privacy concerns due to the unorganized collection of data from multiple devices. As a result of smart city, for example, handheld smart home applications will keep people from being contaminated throughout that outbreak. In general, the smart city idea may be a perfect weapon to battle COVID-19.

IoT sensors and systems produce large volumes of data that have to be analyzed and preserved. The data center's present design is not equipped to cope with the diverse existence and sheer amount of personal and business data [94]. Few organizations will spend enough on storage devices to store all the IoT data obtained from their platforms. Consequently, data for processes or replication would be prioritized based on needs and merit. Data centers would be more broadly spread to increase processing speed and responsiveness as IoT applications are becoming more broadly utilized and use more resources.

When more information is recorded for visualization and interpretation, the use of data mining techniques seems essential. Data consists of conventional discrete data and data streams generated from digital sensors in industrial machinery, vehicles, electrical meters, and crates. These data sets are about position, acceleration, sound, temperatures, moisture, and even chemical variations in the air. Data mining software may focus on corrective mechanisms to resolve urgent operating problems or notify management of results about competitive strategic steps and customer interest shifts that will affect their short-term and long-term market practices. Data needs to be tamed and interpreted using machine and computational methods. Conventional data mining methods are not explicitly relevant to unorganized multimedia content data. There is a lack of qualified data scientists in addition to the need for specialized data processing applications to extract streaming data from sensing devices and multimedia data. McKinsey Global Institute reports that the United States needs between 140,000 and 190,000 additional analytical expertise staff and 1.5 million analytical skills administrators and specialists to make strategic decisions focused on big data research [95].

The first concern is the security of data sent to the server. The HIPAA Protection Act, which provides a detailed list of security policies and guidelines and the applicable contractual requirements, must be enforced by the healthcare sector, including its network operators. Simultaneously, implementing the safety violation warning law for Health Information Technology for Economic and Clinical Health (HITECH) (together with associated enforcement and a significant number of safety violations affecting health data) has placed a heavy focus on maintaining the protection of medical information. One of the most critical and most tightly regulated health facilities' responsibilities is private patient data and medical information security.

Data protection is needed to secure data when it moves into or out of the server, making data obsolete if corrupted. It also requires reliable connectivity to interact, secure window access, and encoded data as it is transferred around the server and into the cloud. Conversely, the encryption process is very computed-intensive, relying on the advanced encryption protocol (AES) technique. This software-based cryptography method is centered on computed-intensive techniques that can influence the efficiency of the computer system, primarily when used ubiquitously to secure vast quantities of data that migrate to and from the server. Due to high-performance overheads, traditional encryption methods can create processing inefficiencies, rendering them less than optimal for securing cloud network capacity. Any application that utilizes OpenSSL will immediately enjoy the benefits of improvements on the Intel framework. Healthcare companies can efficiently use network infrastructure and provide widespread information security to and from the clouds without losing processing performance by accelerating encryption technology, secure session initiations, and bulk data transmission.

1.5 The Framework of an Intelligent Cloud-IoT-Based Monitoring System for Fighting COVID-19 Pandemic

The IoT-based healthcare system is the medical-care-precise variant of IoT that could be introduced to deliver remedy or cure to healthcare professionals and guarantee isolation compliance, which tracks disease sources [96]. With radars' assistance embedded in smart headsets, drones, robotics, and COVID-19, self-sampling experiments and data collection may be performed. The data obtained by these techniques would be forwarded for processing to a central cloud repository. The data created by such a system are provided to healthcare professionals, and government bodies are well prepared to respond to the COVID-19 tragedy. With these results, healthcare professionals will be able to offer more tailor-made electronic wellness appointments for patients. Such electronic facilities will also allow patients to seek more effective treatment while reducing their access and further spreading of the virus at the same time. Agency departments, together with resident public medical offices and the Centers for Disease Control and Prevention (CDC), will be well prepared to distribute resources, assess quarantine needs, track outbreaks, and use this information to enforce emergency plans [96].

The purpose of cloud-based healthcare systems has been sparked by the rising demand for remote patient management coupled with the cloud's storage capacity. Well-implemented surveillance systems have caused the incidence of COVID-19 cases to be minimized and minimize their side effects [97]. The patient and warden make advice about the vital indicators of their situation by multimedia due to patient monitoring's real-time function [98]. Versatile, actual, and hetero connectivity provides a platform for various innovations across the medical field to provide accessibility for participants [99]. This chapter proposes an intelligent cloud-IoT-based monitoring system for combating the COVID-19 outbreak globally. The proposed system allows the use of different wearable devices to monitor a person's health condition during the COVID-19 outbreak. The use of body temperature and pulse, for instance, helps to collect physiological signals. The sensor data collected from these wearable devices will be transferred directly to the cloud network to capture the data captured by these devices. Cloud technology was used due to the small computing power of the device node and storage and to avoid the use of a smart device as a processing device. The design process of the cloud-IoT-based monitoring system for COVID-19 is represented in Fig. 1.3.

The proposed architecture that can monitor people during the COVID-19 pandemic is based on the perceptions of cloud computing and IoT-based technology that accommodates several IoT devices, wearable body sensors or embedded WSNs, and artificial intelligence (AI). In the proposed model, IoT devices are used to collect and capture data and send them through their programmable devices, enabling them to examine the received data. Each device can be considered a diagnostic system due to its program using different machine learning techniques. The devices can be connected to the Internet through the IoT layer. The devices have no energy limitations compared with sensor networks. Hence, they are connected directly to the power. The AI methods become resourceful and paramount to achieve a suitable diagnosis system, and physicians monitor the systems. The systems can report any suspicious patient or person with COVID-19 symptoms to the related experts. As displayed in Fig. 1.3, the framework has three prominent layers.

The IoT-Based Wearable Devices

A wearable monitor and smartphone sensors are attached to the patient's body to gather clinical data. These sensors calculate vital signs, including inundation of blood oxygen, temperature, pulse rate, blood glucose, and SpO_2; a variety of healthcare sensors are available today [100, 101]. It is imperative to track these symptoms in the patient's body because any suspicious data may result in an infection [102]. For example, a decrease in the human body's oxygen level triggers sleep apnea, leading to death. Unusual blood pressure also causes kidney disease or diabetes; all

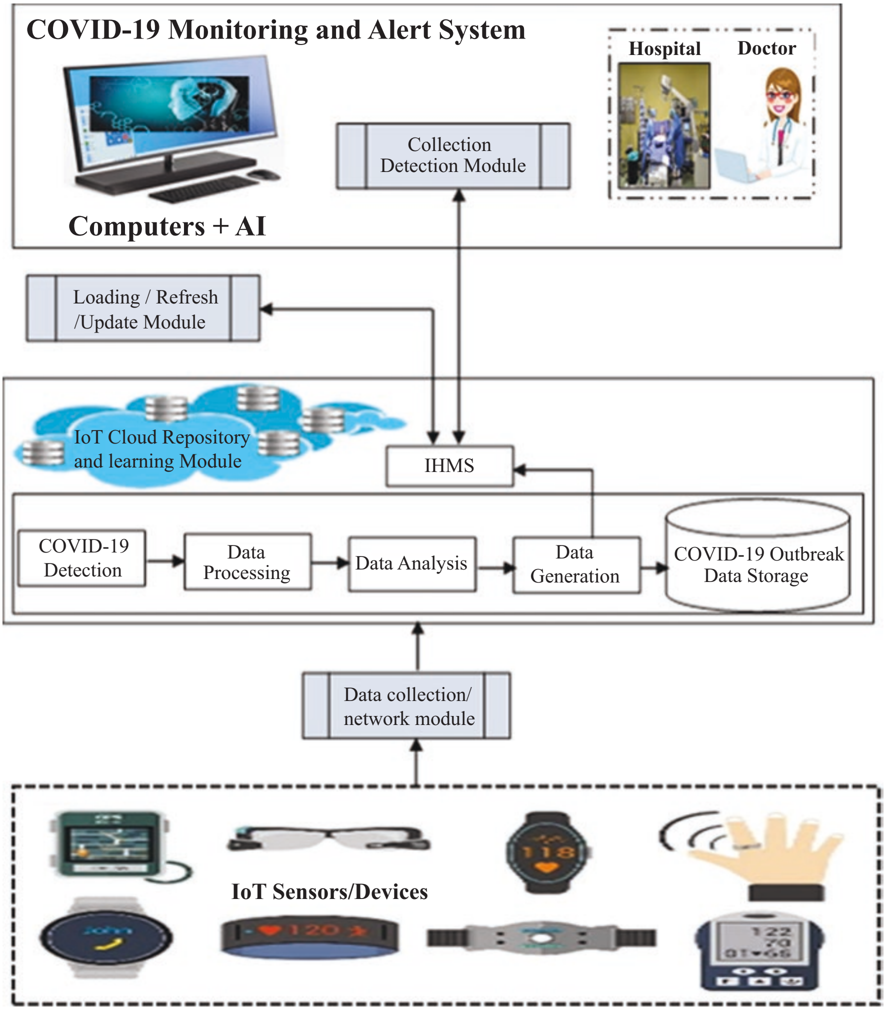

Fig. 1.3 The proposed cloud-IoT-based architecture for COVID-19 outbreak monitoring

these are symptoms of the COVID-19 outbreak, making them essential to monitor people during the COVID-19 outbreak. The sensitive data is transmitted through a Bluetooth connection to the person's mobile app and eventually to a database server. Also, devices can calculate and send data daily without patient intervention to automate it (IoT), thereby improving interface design efficiency and making it more convenient.

Cloud-IoT Based (Data Layer)

The cloud includes the location where information is deposited and processed on the network. Cloud allows patient data to be processed from their mobile over the network, and then, it is eligible for doctor assessments. Therefore, all document collection and handouts will be stored in the cloud for any condition identification in medical information. Thus, the irregular modifications in the patient data will be categorized dependent on patient condition and illness. All documents resulting will be either submitted to the patient and/or doctor's device or emergency room, or both will rely on the patient's condition. Therefore, the cloud-IoT-based monitoring system promotes cooperation and transmission of data through its platform that allows healthcare experts to store customer records, analysis, and diagnostics so that other specialists can automatically read the information around shared interests. It shows the patient records faster and real-time updates.

COVID-19 Outbreak Monitoring and Alert Platform (Hospital Layer)
This framework is the medium by which doctor and other experts track patients' information and sensory data. The physicians can review data from the cloud produced by the program, thereby taking immediate action. Information replication in this application in real time is done by deleting all information from the network server as soon as it arrives to ensure physicians are up to date with the patient's condition, and this helps paramedics take an immediate decision in the event of an emergency until the situation gets worse and avoid hospital admission. The other elements of a supported sensor network are mainly used to manage network pattern settings and connections between device stages and objects. Besides, domain-specific management inside the computer system is accessible in the software application to access and configure the device's similar activities, like active/inactive timestamps and sensing rate. Domain-specific management, therefore, works with both the public network to deploy sensor network configuration and new features and the part to inform/update network providers of the latest changes. Likewise, according to the services given, the data analysis aspect exists within the cloud server to handle data processing activities, such as statistical analysis.

Gateway
This component is responsible for communicating with IoT-based devices and patient devices to identify biological and physiological signs of a person and conduct primary data analysis. The result of this section is a description of the circumstances of patients sent to healthcare experts. Also, the framework can respond to signs of irregularity when it is identified, e.g., submitting a request for assistance (e.g., demand for an assistant care provider) or an urgent request (e.g., call for an ambulance) when an acute condition is detected.

1.6 Practical Case for Cloud-IoT-Based Monitoring System During the COVID-19 Pandemic

The primary essentials of this system's development and the proposed system's execution are discussed in this section, which aims to monitor vital signs for people at home and/or at work during the COVID-19 outbreak. Cloud-IoT-based monitoring system monitors patients' cognitive information like glucose, heart rate, temperature, and blood pressure chosen as these are some of the signs of COVID-19 patients. All information obtained will be transmitted from sensors to gateway and cloud-IoT server to scan for any anomaly or irregularity in the data recorded. Documents for the processing operation will be produced and submitted to the patient's physician and other bodies providing medical care (e.g., hospital) concerning data protection and confidentiality. The system's primary mission is to control physiological information gathered from the portable devices as per time and day, and signified data will be recorded and sent to be processed in the cloud server and ultimately accessed by official healthcare providers and physicians at any time through the dashboard of physicians.

When a link has been established on the cloud-IoT layer, a suitably equipped and validated IoT-based personalized healthcare model (IPHM) could be utilized to test, track, forecast, or evaluate any patient. This system also has an upgrade module that updates the local personalized healthcare model (LPHM) on the mobile phone automatically. In the event that the IPHM's Internet access is interrupted, the LPHM interface operates as the local intelligent device. To perform this switching, the system incorporates a link detection module that automatically detects whether the user's smartphone is connected to the network or not. This connection ensures a cloud-based architecture that is simple, reliable, and accurate for patient evaluation, tracking, forecasting, and treatment planning.

These devices have a remarkable impact on the prompt detection of the COVID-19 outbreak. For instance, IoT-wearable sensors can show any part of them that is not functioning well by capturing each patient's significant medical information. The results from these device users can notice any change in their health condition frequently and book an appointment with a physician before it is generated to actual disease or any symptoms appear [103]. It could be simpler to combat the COVID-19 outbreak by implementing IoT and smart wearables in the healthcare system. Also, remotely monitoring COVID-19 patients would be more convenient and reduce the number of patients admitted into hospital or isolation centers. The following are practical applications of the proposed framework.

For tracking purposes, the smartphone applications are empowered with IoT-based devices providing real-time information using Global Positioning System (GPS), geographic information system (GIS), etc. These have been extensively useful to intensify the chance of monitoring and detecting infected people [33, 104]. The implementation of smartphone applications with IoT-based platforms during the COVID-19 outbreak might benefit from getting a complete cloud service that can be tracked by health professionals and the government for the COVID-19 pandemic and allow the infected person to receive treatment from home. The online hospital and real-time health information can send their health-related records to the cloud using an IoT-based cloud database and receive guidance on fitness online from physicians physically present at the clinic. Treatment is being administered within this platform, and without expanding the contamination, the patient will be cured at home. The system is cost-effective when compared with physical appointments at hospitals and clinics. Reports obtained can be used by the government to make better decisions and action in future pandemics and will be able to manage the outbreak effectively [96].

A smart helmet with a thermal camera is an alternative suitable sensor when compared with the infrared thermometer gun due to its lower human interactions [105]. The image and location of the user's face are taken whenever an optical camera identifies the elevated temperature on a smart helmet and then sent to the assigned cloud-IoT database with an alarm. Then experts can differentiate the infected person and take necessary action immediately. The devices used allow physicians and other related officers to access facial recognition, temperature black spot viewing, and the user's knowledge in the crowds. The smart helmet has the storage capacity to keep all captured data within the helmet and thus serve as a backup for the cloud-IoT database [106]. Moreover, the smart helmet integrated Google Location, and its history can be used to identify the locations reached after discovering the infected human [107]. This wearable device has been used successfully in countries like Italy, the United Arab Emirates (UAE), and China to monitor crowds within two meters and has shown promising results [108]. For instance, a Chinese company produced a smart helmet called KC N901, which has a precision of 96% for elevated body temperature discovery and has been used by the countries mentioned above [109].

1.7 Conclusion and Future Directions

The global epidemic of COVID-19 has become the primary hub of scientific research. The new digital technologies will act as a perfect solution to this worldwide crisis. Cloud- and IoT-based monitoring systems can address detection, surveillance, mapping contacts, and controlling this viral infection. The introduction of cloud-IoT-based technologies to the present COVID-19 pandemic situation can build a social forum to help individuals access appropriate treatment at home and develop a robust repository on disease control for the government and healthcare organizations. The use of cloud-IoT-based healthcare devices can be used for diagnosis and obtaining data from a person with minor symptoms (preventive disguises, thermometers, medicines, personalized COVID-19 infection diagnosis, and control kits). Patients could submit their general well-being to the server clinical data storage online regularly and exchange their relevant data within hospitals, the Centers for Disease Control and Prevention (CDC), and national and local healthcare offices. Therefore, this chapter proposed an intelligent cloud-IoT-based monitoring system framework to fight the COVID-19 pandemic.

The chapter first presents the roles of IoT and cloud computing technologies in battling the COVID-19 outbreak. The framework can be used to obtain real-time data and information, which can be used by physicians and relevant experts in clinical sciences. The proposed framework is a platform that incorporates various IoT-based devices and includes generic on-board computational resources for detecting individual incidents, warnings, and interacting with numerous health information system providers. This is designed to provide enhanced supervision for patients during COVID-19, data collection in certain specific cases, and remote assessment for the patients. In the ongoing COVID-19 disease outbreak, IoT is offering so many innovative cloud-based facilities and infrastructure to more effectively support patients. During such a crucial period of lockout, the remote healthcare network has much sense. The system collects biomedical data from patients through smart technologies and transmits it to the cloud-IoT server to analyze and process the data. Thus, any identification of abnormality in patient information will be reported through the COVID-19 monitoring and alert platform to the patient's physicians. The cloud-IoT system has a treatable framework that can easily scale and extend, thus offering efficient, cost-effective applications for remote monitoring of the COVID-19 outbreak. Furthermore, the system's performance can make a positive contribution accurately to the improvement of medical care facilities using an impeccable device capable of tracking clinicians wirelessly and promptly. The system helps to control and manage people who are in remote areas for their medical needs. Future work will look into the security, privacy, confidentiality, and mobility control of the cloud-IoT-based system.

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