Internet of Things and Web Services for Handling Pandemic Challenges

Duddela Sai Prashanth, Janardhana Swamy, and Shreyas Suresh Rao

Abstract Within the past few months, the COVID-19 pandemic has disrupted millions of lives and caused unforeseen economic damage, whose impact is both significant and far-reaching. There is an immediate need to utilize emerging technologies across various industries to fight the pandemic in this light. Internet of Things (IoT) and Web Services (Cloud services) are two such technologies that provide promising solutions to combat the virus outbreak. To monitor, track, and control the spread of viruses during the pandemic, IoT and similar sensor-based technologies have been employed. Innovative technologies that enable monitoring of health delivers live observation by using smart devices to monitor the health and can handle remotely with support of cloud and Artificial Intelligence. The HMS establishes a secure remote monitoring system between patients and doctors, facilitating telehealth services to be rendered. For tracking, the HMS uses a combination of personal health data and social data in real-time, enabled through technologies such as Machine Learning, distributed Cloud computing, and AI-based speech recognition. Because of lightweight Application Programming Interfaces (APIs) and edge computing capacity, the IoT-enabled HMS is now accessible through mobile apps and web-based applications. Web services are playing an integral role in Industry's response to fight the global pandemic. To access the data on the COVID-19 provided by World Health Organization a separate interface is provided over a web service. Some other RESTful APIs to track COVID-19 include: CORD-19, deployed on Vespa Cloud, that enables search and navigation on Open Research Dataset; CoronaTab that provides localized health information; COVID-19 India API sourced from the Ministry of Health and Family Welfare that retrieves case counts, testing statistics and hospital data from the Indian subcontinent. Cloud-based services are employed to support remote work-from-home operations, e-commerce, retail, healthcare, and entertainment segments, to name a few. Enterprises effectively use cloud services to build robust and disaster-averse networks worldwide to respond to a distributed workforce and protect data and business applications' integrity. Another sector is the energy and utility verticals, which uses IT service management (PaaS and SaaS) and infrastructure (IaaS) for digital transformation during this pandemic. This chapter

D. S. Prashanth (✉) · J. Swamy · S. S. Rao
Department of Computer Science and Engineering, Sahyadri College of Engineering and Management, Mangalore, India

R. Agrawal et al. (eds.), *Sustainability Measures for COVID-19 Pandemic*,
https://doi.org/10.1007/978-981-16-3227-3_1

discusses how IoT and Web services support handling global COVID-19 challenges, especially in Healthcare, retail, and social sectors.

Keywords IoT · Web services · COVID-19 · Digital transformation

1 Introduction

The Internet of Things (IoT) and Web Services are two emerging technologies that offer promising solutions to combat the COVID-19 pandemic. In this chapter, we discuss the solutions, from a literature perspective, regarding first IoT, then Web Services, for handling the pandemic challenges.

Many smart devices are connected over the internet and often exchange data that makes the networks more complex [1]. This helps to convert normal devices into innovative devices. Interaction with the devices is not required for these smart devices, they communicate with each other over the internet and accumulate data in the respective clouds [2]. The number of smart devices is increasing exponentially and IoT is contributing to the present digital era [3].

IoT has the ability to revolutionise a number of sectors, including health care [4], self-driven vehicles [5], home and robots for industry [6], industrial automation [7], energy storage [8] and more.

Global attention is gained to most of the new technologies in the form of IoT [9]. It becomes easily accessible to predict, prevent, and monitor the incipient infectious diseases [10]. Patterns are identified from the raw data collected from different sources like interconnected smart devices, sensors, and similar are often referred to as IoT. Health Monitoring System with State of the art included for observation over the wearable devices to monitor health. These devices are cloud-based that help to monitor health remotely, and AI is included for better services. These monitoring systems use digital platforms, survey records, and healthcare info, incorporating managed, unsupervised, and machine learning techniques. When technologies like AI and machine learning combine with the cloud for storing, blockchain for security and automation using system software with AI speech recognition, the health monitoring systems produce a consistent remote monitoring system. These IoT-enabled healthcare delivery systems provide features like digital triage, AI secure chat, and telecare. These technologies are now readily available via simple user interfaces on secure mobile apps and web-based applications, thanks to lightweight Application Program Interfaces (APIs) and edge computing capabilities.

Different technologies can communicate data through the network to anywhere around the World automatically where computing devices are included that are interconnected, electronics with digitalization, electrical, and medical devices [11]. IoT technologies have made the transmission of data an easier task [12]. The identification numbers or codes used for authentication or authentication are essential for all interconnected IoT platform devices. IoT currently provides a connection to multiple

approaches, quick analytics, machine learning, deep learning, and deep learning for every application that works [13].

Societies face various challenges in healthcare, training, construction, supply chain management, service delivery, travel, and tourism under present conditions and in a post-COVID-19 environment. Health care services are overloaded because of the exponential rise of COVID-19 cases, and it creates problems for regular patients who need medical assistance. The limited movements, which is a significant problem for the healthcare sector, lead to delay and increase the demand for resources. For tracing the people's contact, a practical and automated contact tracing application must regulate the spread. It is the responsibility of different sectors like engineering, healthcare workers, policymakers, research communities, and the public to join and provide a solution for such problems.

Digitalization and the use of telecommunications would be needed to protect and manage the post-COVID-19 environment. Artificial intelligence (AI), big data, 5G communications, cloud computing, and blockchain, among other emerging innovations, will play a crucial role in fostering the system's security and development for people and ecosystems. To incorporate these promising innovations and realise their advantages, technology and engineering managers will have to address major challenges and carry out complex managerial tasks in terms of cost, scope, performance, resource management, and risk management.

1.1 IoT Process to Combat the Covid-19 Pandemic

IoT is a useful technology platform in order to fight the COVID-19 pandemic, which will face significant challenges during the lockout scenario. This technology helps capture the infected patient's real-time information and other required information [14, 15]. Figure 1 illustrates the essential processes used for COVID-19 by IoT. IoT is used to collect health data in the first step of different infected patients' locations and use the virtual management system to handle all data [16, 17]. This technology allows the data to be monitored, and the report achieved to be followed.

Advantages by using IoT to combat COVID-19 are Reduced chance of mistakes, Lower expenses, Superior treatment, Lesser expenses, Effective control, and Enhanced diagnosis.

The rest of the sections are organized as follows. Section 2 describes the IoT applications used to combat the COVID-19 pandemic in medical Healthcare, smart home, and IT. This section also enlists some significant challenges faced for IoT implementation. Section 3 describes the various Web Services/Cloud Services used in the Industry/E-Governance sectors to fight COVID-19, and lastly, Sect. 4 concludes the chapter.

Fig. 1 IoT process for controlling Covid-19 pandemic

2 IoT for Handling the Pandemic Challenges

The IoT's important goals include developing a smart environment and self-aware autonomous devices, such as smart living, intelligent products, smart health, and smart cities, among others [2]. The following section addresses IoT implementations in the fields of Industry, medicine, and home automation.

2.1 Literature Survey

The author provided a methodology for effective utilization of 5 g for e-health use cases and its role as a facilitator of related online services [18]. Using wireless communications innovation, a low-cost IoT—based smart sensing system is built to assist, communicate, and reduce the covid-19 challenges [19].

To understand the human-technology relationship, providing a framework results in practical observations for controlling virus transmissions during pandemics [20]. The integration of 5 g IoT provides creative solutions for technological requirements and challenges in telemedicine, contact tracking, education, retail, production lines, e-government/remote office/information sharing, smart manufacturing and factory automation, e-tourism, and entertainment. It implies that IoT combined with 5G will make everyday life, work, and other aspects of human life simpler in the future [21].

The smart healthcare devices are implemented to identify the impact of COVID-19 and safeguard diabetic patients [22]. Gives an overview of the success of sensor-based E-health in the control of worldwide pandemics and how this pandemic situation has made rigorous development in the IoT network [23]. Made a significant contribution

to a deeper understanding of recent technical progress in IoT implementation areas, as well as the environmental consequences of increased IoT product adoption [24].

Implement IoT that discusses IoT's internal and external factors and deployment to detect possible challenges [25]. It is found that IoT enabled healthcare networks are useful to identify infected patients of COVID-19 and can provide better treatment for a speedy recovery of patients [26]. The smart IoT enabled wearable device is used to fight against COVID-19 pandemic challenges related to hygiene and disease prevention [27].

By using an integrated network, a healthcare system allowed by the Internet of Things (IoT) is useful for the proper check of patients with COVID-19. This technology boosts patient satisfaction while also lowering hospitalizations [12].

IoT offers the components needed to assist nations in reducing the effects of COVID-19. IoT has a broad variety of technology that can easily guarantee that almost all of the health officials' protection and precautionary recommendations are followed [12].

2.2 IoT in Personal Medical Devices

Medical care's primary goal is to guarantee the system's safety to keep patients safe from pernicious attacks. IoT has significant applications in medical fields during Covid-19, which are:

1. Internet-connected hospital: A fully integrated network inside hospital premises must introduce IoT to support a pandemic like COVID-19.
2. In the case of an emergency, alert the medical services involved: Where possible, this integral component would allow students and families to react better and quicker.
3. Transparent COVID-19 treatment: Patients should realize the profits without prejudice or advantage.
4. Standardized care process: Selecting therapeutic options becomes more effective and helps with case management.
5. Telehealth consultation: Using well-connected teleservices, this mainly makes healthcare accessible to those in need in rural parts.
6. Wireless healthcare network to classify patients with COVID-19: It is possible to mount different legitimate apps on smartphones, making the recognition process simpler and more fruitful.
7. Fast tracing of patients who have been infected: In the end, the impactful tracing of patients enhanced the treatment of cases more intelligently by service providers.
8. During the propagation of this virus, real-time information: Because the computers, sites, networks, etc. are well aware and linked, it is easy to exchange information on time and cases can be treated correctly.

9. Quick COVID-19 screening: As soon as the condition is received/discovered, smart linked treatment devices will be used to attempt a medical evaluation. As a result, the overall screening procedure becomes far more efficient.
10. Identify ground-breaking solutions: The most significant aim is to increase the general quality of supervision. It can be done by taking popular inventions to the bottom level.

They have their predefined targets at the stage where attackers target mobile phones. Typically, their point is to take the data, attack gadgets to use their properties, or shut down specific programs that check patients' conditions. There are various forms of attacks on medical devices that involve stealthy listening. The patient's protection is spilled, uprightness error in which the message is altered, and usability problems include depleting battery assaults. Some advanced security threats associated with the safety, security, and prosperity of patient remedial data are discussed as follows:

1. For any errand that uses battery power, PMDs are fundamental. Therefore, restricted encryption must support these gadgets. If the device is a component of different systems, there will be a high risk of confidentiality, accessibility, protection, and trustworthiness at that point.
2. Because PMDs have no remote correspondence validation instrument. So, the information put away in the gadget could be effectively assessed by unapproved individuals.
3. Besides, the absence of safe validation exposes the gadgets to various other security dangers contributing to vindictive assaults. An adversary can dispatch denial of Service (DoS) attacks.
4. Patient information is transmitted through the communication medium, which may be changed by unapproved parties, so a patient's protection may be unfortunate.

2.3 In Smart Home IoT

The IoT brilliant home administrations are expanding step by step [28]; advanced gadgets can adequately speak with one another using Internet Protocol (IP) addresses. In a keen home environment, all savvy home gadgets are associated with the web. Insidious attacks become more likely as the number of devices in the intelligent home province increases. When smart home systems are controlled independently, the number of instances of vengeful attacks reduces. Wherever and wherever keen home devices can be reached across the network. It generates the chances of malignant attacks on these gadgets in this way.

There are four parts of a vibrant home: administration level, brilliant gadgets, home door, and home system. Numerous devices are connected to an intelligent home and exchange knowledge using a home device cleverly. Therefore, a home portal governs the advancement of the data between the external system-related

gadgets. The administration process utilizes specialist co-op administrations that relay different administrations to the home system.

2.4 In IT Sector

The IoT has provided a fair opportunity to create powerful modern frameworks and applications [29]. The approved person will screen the current area and create a vehicle in an intelligent IoT transportation system. Likewise, the authorized person will predict his future location and street traffic. The word IoT was used in the previous process to differentiate one of a kind from RFID products. To date, specialists have correlated the term IoT with sensors, tools, mobile phones, and actuators of the Global Positioning System (GPS). Recognition and management of emerging IoT technologies are mainly focused on information protection and data security. The IoT provides various linked, monitored, and observed items, resulting in valuable data and private information. Security assurance is an increasingly fundamental problem in IoT conditions instead of conventional systems since the amount of IoT attacks is high.

2.5 Challenges of IoT in the Wake of COVID-19

Development of IoT for more comprehensive applications and devices is a challenging task for any organization. During development of applications of IoT, numerous hurdles are tangled that are mentioned.

Scalability Enforcing IoT to tackle the global pandemic of COVID-19 poses a significant challenge in terms of functionality. The Internet of Health Stuff (IoHT) necessitates a vast number of devices to reliably feel and relay patients' symptoms to the network. As of now, there are nearly 3.7 million active cases worldwide. Multiple sensors are required for each IoT system. Furthermore, because of scalability, energy requirements have increased.

Limited spectrum and bandwidth The need of data is more to communicate the data from different sensors to the cloud storage, this data is collected over numerous IoT devices. Currently, the majority of IoT devices depend on mobile operators' licenced spectrum. The bandwidth requirements have risen in parallel with the growth of these devices. The data is subjected to delay, which may result in incorrect data transmission. Operators use Wireless for specific IoT, that becomes unstable as the number of Devices in the service area increases. Many IoT devices currently rely on 4G/LTE infrastructure to complete their tasks. Many IoT devices would soon outgrow this restricted range of 3G/LTE/4G.

Security and privacy issues Conventional authentication methods are not areas comprising to enforce protection in IoT because of its adaptability and energy

constraints of IoT devices [30]. To provide end-to-end data protection, user privacy, and safe authentication, energy must be utilized optimally for security mechanisms, and techniques recognized to reliable the Iot system should have lower computational burden [31]. As a consequence, IoT authentication must be implemented using lightweight encryption methods. The security requirements of IoT enabled systems also increased significantly of the coronavirus pandemic.

The security concerns in implementing IoT concerning COVID-19 are:

(i) The information that was sent to the devices installed to the COVID-19 patent's body must be reliable,
(ii) The information should achieve its goals effectively,
(iii) The information must not be manipulated, and
(iv) The data must not be captured from the communication path, and
(v) The data stored in the IoT device's memory should not be accessible to everyone [32].

Big data centers Most information is recorded at data centers since each IoT system transfers information to the server through a pre-defined Application Interface (API). One of the most challenging aspects of adopting IoT to fight COVID-19 would be that it necessitates huge storage centers that can handle all of the necessary data without it being overburdened.

2.6 Uses of IoT for COVID-19 Pandemic

IoT is a modern technology that guarantees that patients infected with coronavirus need to quarantine for a defined time period to monitor the virus's spread to normal individuals [12]. During quarantine, careful monitoring is required to provide the appropriate precautions to save survival. By the use of Internet-based network systems such as IoT, COVID-19 patients are monitored very easily. Biometric technologies are now built into platforms for IoT and biometric measurements such as blood pressure, heartbeat, glucose level, breath analyzers, etc. The productivity of medical personnel and patient satisfaction is increased by combining medical measurement instruments and the Internet and computers, and the workload of medical staff with existing resources or equipment is also reduced. Health services are given to patients with minimum costs and higher patient satisfaction in the latest pandemic crisis of COVID-19 for the entire globe. Figure 2, the areas where IoT flourish because of the impact of COVID-19.

IoT devices and applications, including wearables, drones, robots, IoT buttons, and smartphone applications that are mainly utilized in the forefront of combating COVID-19 [33].

Wearables The mixture of technology and things that can wear, is known as Wearables in IoT. It is foreseen that healthcare workers will be spending twenty billion

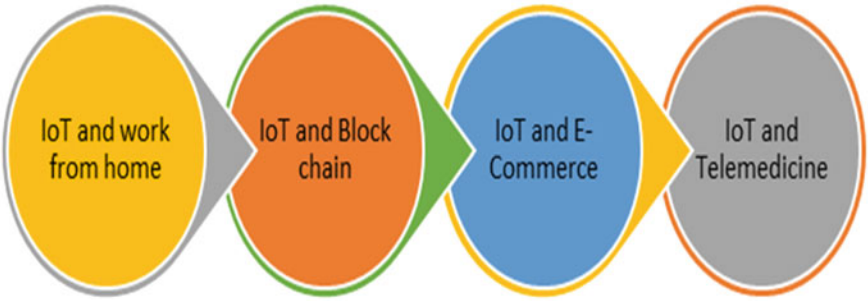

Fig. 2 Areas that flourish because of COVID-19 impact

dollars annually till further couple of years on wearable IoT devices. This helps to monitor more patients. IoT devices in health care make work easier to monitor temperature, and other health parameters using smart devices. It is not limited to health care but IoT becomes a part of day to day life.

Drones Drones are simply aircraft that are flown without any or minimal human operation by remote monitoring. Different types of IoT-based drones, including thermal imaging drones, disinfectant drones, medical drones, surveillance drones, announcement drones, and multipurpose drones, are used in the healthcare domain particularly, in the fight against COVID-19.

Robots A robot is defined as "a machine that resembles a living creature in being capable of moving independently".

IoT Button This type of IoT device is a small, programmable button connected to the cloud through wireless communication. The IoT button enables patients to complain if any hospital restrooms need cleaning by pressing a control only.

Smartphone Applications Many smartphone applications have been developed for the healthcare domain, and some of them have been used in response to COVID-19, namely nCapp, DetectaChem, Stop Corona, Social Monitoring, Selfie app, Civitas, StayHomeSafe, AarogyaSetu, TraceTogether, Hamagen, Coalition, BeAware Bahrain, Houska, and Whatsapp.

2.7 Practices Involved in IoT for Tracking COVID-19 Patients

IoT and related applications are termed as an innovative technology that acts as a platform for integrating different systems or processes. IoT is perfectly suitable and helpful in detecting real-time data from patients infected with the coronavirus.

Initially, the virtual management tool is created in the IoT database to collect information from different locations from infected COVID-19 patients and analyze the data obtained. Then IoT can be used to review the data and report received. IoT is a conceptual network created by joining more than one or more objects or sensors and systems to control the efficient flow of COVID-19 pandemic data through data exchange among cloud systems from anywhere [34, 35]. As stated earlier, monitoring of corona virus-infected patients can be achieved effectively by implementing IoT and allied techniques in the current COVID-19 pandemic, and suspected cases can be detected. Complete assurance can be provided to patients. In this situation, the monitoring of a cluster can be significantly developed by establishing a well-organized community of linked networks based on the Internet [36]. The COVID-19 community can be built on smartphones with the aid of IoT platforms so that patients or other needy people can benefit from it. It is essential to update the monitoring of COVID-19 symptoms in real-time and the recovery rate to the controller, such as physicians, doctors, healthcare staff, etc. Thus, significant measures can be taken to optimize the overall quarantine duration [35].

In combating a global virus pandemic, IoT technologies' implementation results in well-defined hardware, Software, and related policy ecosystem. This segment discusses the components of this particular healthcare environment based on results from the research surveyed. A niche collection of well-integrated components is developed by the sensibility of handling an outbreak with IoT-based technologies. As part of an ecosystem powered to combat and mitigate a virus's spread, these components work together. Many advantages with using IoT to fight a pandemic, such as COVID-19, involve improved patient treatment accuracy, reduced prices, more effective surveillance, quicker treatment, and better treatment choices [12].

2.8 Global Technological Advancements to Resolve COVID-19 Cases Rapidly

The Indian government has initiated e ArogyaSetu, a mobile application aimed at overcoming the COVID-19 pandemic and making people more aware of it. It aims to create a connection between the valuable player healthcare services and India's population. Similarly, China's civilians have access to a smartphone application called e Close Touch (English translation). This app notifies the app's owner of the proximity of a corona-positive user. To be capable of walking around with great care. The US government will finish its fiscal year in April 2020. Will soon be releasing a similar kind of smartphone application for its people.

After China, Taiwan was the most likely country to have more COVID-19 incidents. Nevertheless, Taiwan rapidly militarised and adopted unique methodologies to protect the population's health for any possible coronavirus case detection, containment, and resource provision. Taiwan provided and integrated its immigration department with its national health insurance database and took a catalog to instigate big

data for analytics; during a clinical visit, Taiwan developed real-time warnings based on the age of travel. Case detection is assisted by medical signs. They've also used cutting-edge technologies, such as QR code scanning, summary history monitoring, and so on, to identify sick individuals [37].

IoT technology has several characteristics. Here we can take into account those features because of which IoT applications are highly recommended in medical files supported by IoT applications/devices with seamless connectivity; medical staff can remotely track Covid-19 patients as well as self-quarantine individuals [38, 39]. Compared to the overall number of infected or suspected Covid-19 viruses, the number of medical employees is not accessible. Medical staff will collect the required criteria from these patients in one place with IoT applications' data protection and decide on further action [40]. IoT systems are simple to use so that patients can handle these applications on their own [41]. The IoT, Statistical techniques, Big Data based application offers an excellent level of accuracy with lower implementation costs. These techniques help in deciding the factors which are affecting during Covid-19 lockdown and suggesting precaution measures for the same [39, 42–45]. We can also save the lives of our medical personnel, laws, and policies by using such Software.

3 Web Services for Handling COVID-19 Pandemic Challenges

Web services are playing an integral role in Government and Industries' response to fight the global pandemic. Broadly, web services are used to access COVID-19 data, contact tracing, support Work-From-Home activities, and overcome challenges in the healthcare and retail sectors. Also, Industries are embracing Micro-services technology for developing resilience during pandemic times.

Each of the approaches above is explained in the subsequent paragraphs.

3.1 Accessing COVID-19 Data

Governments of different countries and private enterprises have developed web interfaces for COVID-19 data access. Notable ones include:

Athena API The World Health Organization (WHO) has released the Athena Web Service, which provides a RESTful interface to access WHO's data and statistics on the COVID-19 pandemic. Athena API supports CSV and JSON file formats for data interchange, allows querying against multiple WHO data sources simultaneously, and provides filter options for response download [46].

CORD-19 Deployed on Amazon Web Services Cloud, the service endpoint allows end-users to query the COVID-19 Open Research Dataset (CORD-19), using natural

language. The search results are processed using Amazon Comprehend Medical, which is updated regularly. The service answers Corona symptoms, infection rate, prevalent antibodies, vaccination options, their efficacies, clinical treatment, etc. The service responds to queries regarding virology, immunology, epidemiology, and genomics regarding the coronavirus [47].

Corona Tab This is deployed on the Programmable Web and provides localized COVID-19 data. The service offers a dashboard, REST API, and is localized in many languages. The endpoints are cached for one hour through Cloud flare [48].

COVID-19 India API Sourced from the Ministry of Health and Family Welfare retrieves case counts, testing statistics, and hospital data from the Indian subcontinent.

Postman COVID-19 API Resource Center provides critical real-time data as a service via the Postman REST APIs. This data can be consumed by front-line health care workers such as Doctors, Researchers, Government officials to access critical real-time data on COVID-19. The services are grouped into three categories of (a) Featured API Collections, (b) Twitter API Collection, and (c) Additional API Collections [49].

(a) **Featured API Collections:** This includes a set of four APIs. The first is the COVID Tracking Project API which collects SARS-Cov-2 testing data from 50 US states and 5 US territories. The second API is the Novel COVID API, which provides information on the current cases. This API refers to multiple data sources such as Worldometer, COVID-19 Time Series Summary, DATI COVID-19 Italia, Ministry of Health and Family Welfare for Government of India dataset, GOV.UK Coronavirus (COVID-19) in the UK dataset etc. The third API is COVID-19 Rich Data Services, which offers curated, high-quality data, and metadata from important Corona Virus datasets across the World. The fourth API is the Global Coronavirus API, which contains current and historical datasets for data scientists, researchers, and healthcare professionals to understand and provide timely interventions to the virus.

(b) **Twitter API Collections:** Twitter is an essential social medium for displaying vital information related to COVID and sharing the tweet accounts of important Government officials and healthcare workers whom the common public can contact during pandemic times. The Twitter API collection contains APIs for standard search COVID-19 search terms, tweet accounts of US State Government officials, US State Governors, and US State Health Departments.

(c) **Additional API Collections:** These are the other collections submitted by the community to fight the Corona Virus. Notable ones include DATA API, which provides the global statistics, country statistics, and timeline of the virus; Health API provides the global Corona statistics by country and state; Smartable.ai that provides the latest and historical news of the virus; Statistics API, which displays the public data collected by John Hopkins. The country-specific APIs also show country-based Coronavirus statistics for Japan, Canada, India, the US, the Philippines, etc.

3.2 Contact Tracing

Apple Inc. and Google released Exposure Notification API (also called Contact Tracing API) in April 2020 [17], which helps developers with public health authorities use Beacon technology to detect proximity among the people. The Apple-Google framework API uses Bluetooth and cryptography to see people's proximity and is deployed on Google Playstore. Once the end-users download this app from the Playstore, the app collects the user's necessary profile information. Furthermore, the person has to update his/her COVID-19 status on the app. Subsequently, the app shall use its API to notify the COVID status of the meeting person. However, one disadvantage of the Apple-Google framework API is that it cannot trace its location.

Governments in Europe, Asia, the United States of America, and other countries across the World mine the mobile phone location of users to detect symptomatic COVID-19 patients; this technique is called 'contact tracing.' Chinese use the 'Alipay Health Code' App, Indians use the 'Arogya Setu' app, Norwegians use the 'Smittestopp" app, Singaporeans use the 'TraceTogether' app for contact tracing. All these apps use Bluetooth signals between mobile phones to track the symptomatic and asymptomatic patients in a crowd. They use REST APIs for data collection and communication with the Government data sources (such as the Johns Hopkins Coronavirus Resource Center in the US).

3.3 Support Work from Home Activities

The Corona Virus pandemic has necessitated employees across the World to work from home (WFH) [50]. The success of WFH activity largely depends on the Cloud Computing platforms that support WFH. For example, employee meetings are conducted using Zoom, Google Meet, and Microsoft Teams platforms. Increased remote work is made possible through the Cloud Computing Environment (CCE), which consists of deployable Software as a Service (SaaS) cloud services that enable WFH. In the educational sector, Universiti Sains Malaysia (USM) has taken a lead role in allowing e-learning SaaS platforms for teachers and students to interact and conduct classes [51]. The same approach is followed by leading Universities of the World, such as Harvard University, Stanford University, and the University of Jordan.

In the IT environment, to facilitate better WFH facilities during the COVID-19 pandemic, IBM has announced two new services, namely CCE Migration Services and CCE Deployment services, that helps enterprises migrate their existing on-premise applications and data onto the IBM Cloud environment to assist in better WFH environment [52]. The CCE environment provides the WFH facilities at a lower cost, albeit with greater flexibility, security, and agility.

Blackboard Learning Management System [53] is revolutionizing the EdTech platform, used by over 100 million people, especially during the COVID-19 times.

The services are hosted on Amazon Web Services (AWS), which connects learners and educators worldwide to collaborate and create a meaningful online teaching experience.

3.4 Overcome Challenges in Critical Sectors

Here, we discuss the various challenges posed due to the COVID-19 pandemic on the Cloud Services sector, security-wise, and later in the healthcare domain.

Unexpectedly, the COVID-19 pandemic has given rise to a new terminology called "Home-to-X" [54]. Home-to-X services include Home-to-Business (H2B), Home-to-Consumer (H2C), and Home-to-Government (H2G). The virtual meetings, virtual classrooms, digital Healthcare (via telemedicine) poses a "security" risk to the Home-to-X establishment, as shown in Fig. 3. Healthcare data collected from the patients remotely, Virtual Private Networks data transmission vulnerabilities, can be classified under "data privacy." COVID-19 has turned into a digital transformation enabler since millions of people across the world use the Internet services provided by ISPs (Internet Service Providers). Netflix, Zoom, and Webex have compromised on the data security provided via the Internet due to an explosion in data usage [55].

Because of the Work-from-home imposition on several office workers due to the pandemic, large volumes of data (big data) is getting generated in most sectors [56]. The computation (cloud services) and storage of this big data pose an immense challenge since enterprises were not ready to support the vast volume, both infrastructure-wise and technology-wise. The big data presents the application issues of Home-to-X.

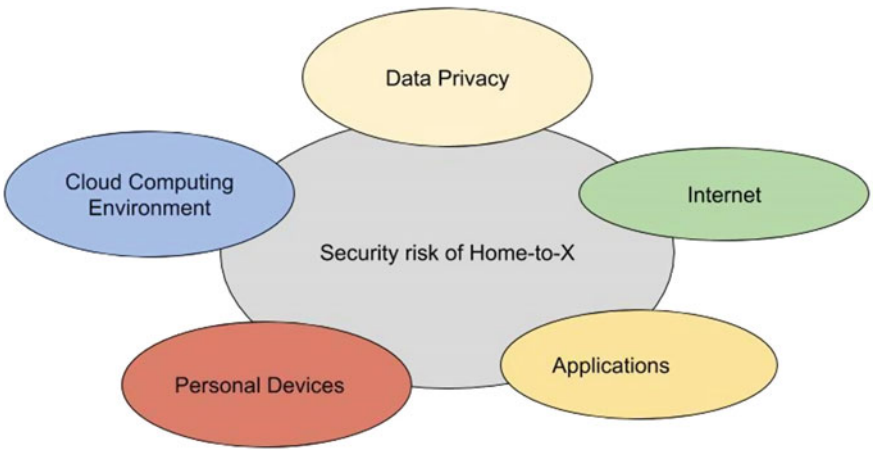

Fig. 3 The security risk of home-to-X

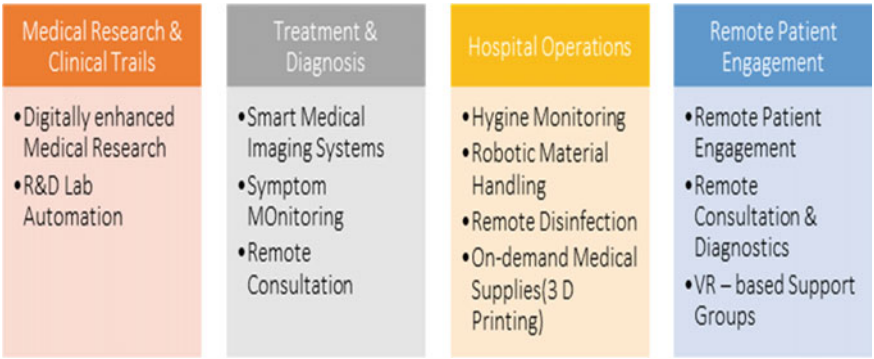

Fig. 4 IoT use cases across healthcare [57]

3.4.1 Healthcare

Diagnosis of COVID-19 through scrutinizing of X-Rays is a crucial element in preventive Healthcare. The paper [58] implements a free web service that classifies an input X-Ray image as COVID-19 or non-COVID. The classification algorithm is based on two deep learning models, wherein the first differentiate whether an input image is an X-Ray or not based on Mobile-Net architecture. In contrast, the second one identifies chest X-Ray images based on characteristics of COVID-19 based on DenseNet architecture. This web service can be used in telemedicine services by the health personnel or directly employed by the patient to self-detect COVID-19 based on chest X-Ray reports.

The availability of accurate epidemiology, laboratory, and clinical data is vital in fighting the COVID-19 pandemic. This data helps the Government to frame policies and guide public health decision-making. The epidemiological data provide a baseline for understanding the disease's transmissibility rate, identifying the risk factors of disease spread, and understanding the containment efforts. While the data is publicly available through google sheets and GitHub repository, a service is implemented to display the data in a user-friendly format. Figure 4 demonstrates the use case of IoT across Healthcare.

3.4.2 Retail

The COVID-19 pandemic has changed the way companies communicate with their customers. Organizations must reply with intensity, compassion, and kindness as customers demand virtual and touchless interactions that protect their wellbeing and inspire trust.

For the mobile app designers working on proximity-based technologies that use IoT, iBeacon technology is an excellent opportunity to design a resilient UX app.

Beacons are small, Bluetooth supportive wireless sensors that communicate with other smart devices or apps by broadcasting radio signals.

"Eggcellent," a restaurant in Tokyo specializing in egg cuisine, developed an egg-shaped porcelain beacon placed on dining tables. The porcelain beacon synchronizes with a beacon-enabled app that takes food orders and receives payments from customers. The app uses the REST Web Services API for communication. Organizations need to invest in building such resilient iBeacon apps that have use cases in the airline industry, home automation, service industry, retail, education, and entertainment.

From a design perspective, first, the beacon-enabled apps must grab user attention and provide useful content through a seamless, frictionless experience. Second, the app must engage the customers in meaningful dialogue, collect relevant data, and perform analytics, enhancing customer relationships. The analytics can be used to entice potential customers with relevant offers, thereby generating more revenue.

3.5 Adoption of Microservices Technology

To develop resilience during the COVID-19 times, enterprises need to adopt the "Microservices" architecture and thereby move from Cloud Virtualization to Containerization.

Unlike traditional virtualization, where hypervisors virtualize the physical hardware, containers virtualize the Operating System to contain the application along with dependent libraries. One can use container orchestration systems such as Kubernetes or Docker Swarm to automate container management, scale, and route.

Containerization enables the adoption of "Microservice" architecture, where the application is designed as a collection of loosely coupled services. Adoption of microservice architecture to App creation will increase resiliency and minimise time-to-market. Microservices are computer and platform agnostic. Offer consistent user experience across mobile, web, wearable environments.

As one of the first successful cases, Walmart Canada handled a transaction of 6 million page views per minute by adopting the microservice architecture. This success is replicated by several multinational companies such as Amazon, NetFlix, PayPal, Twitter, and eBay using microservices. DevOps practices of continuous integration and delivery is an enabler for microservice deployments.

As evident from Fig. 5, over 63% of enterprises are either transitioning or have fully microservice-based applications, while 21% are actively considering adopting the technology. Unforeseen circumstances such as the COVID-19 pandemic necessitates enterprises to embrace the microservice-based delivery model to build IT resilience proactively since microservices improve fault isolation and eliminate vendor and technology lock-in, favors continuous deployment using the DevOps model, and is scalable.

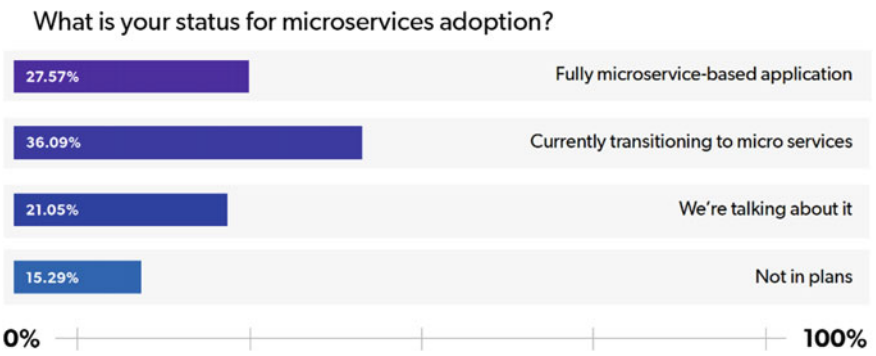

Fig. 5 Microservices adoption in enterprises (*Source* JRebel Java Microservices report, 2020)

4 Conclusion

IoT and Web services are emerging technologies that play an integral role in Government and Industries' response to fight the global COVID-19 pandemic. This chapter describes how the IoT applications are used to combat the COVID-19 pandemic in medical Healthcare, smart home, and IT. Further, the chapter throws light on some IoT implementation challenges. Web/Cloud services are used to access COVID-19 data, contact tracing, support Work-From-Home activities, and overcome challenges in the healthcare and retail sectors. By transitioning from Cloud Virtualization to Containerization, the adoption of Microservices technology builds resilience in the IT enterprises and helps overcome the COVID-19 challenges.

References

1. Srinivasan, C.R., et al.: A review on the different types of internet of things (IoT). J. Adv. Res. Dyn. Control Syst. **11**(1), 154–158 (2019)
2. Dai, H.-N., Zheng, Z., Zhang, Y.: Blockchain for internet of things: a survey. IEEE Internet Things J. **6**(5), 8076–8094 (2019)
3. Al-Garadi, M.A., et al.: A survey of machine and deep learning methods for internet of things (IoT) security. IEEE Commun. Surv. Tutorials (2020)
4. Saranya, K., Durga, et al.: IoT-based health monitoring system using beaglebone black with optical sensor. J. Optical Commun. 1.ahead-of-print (2019)
5. Minovski, D., Åhlund, C., Mitra, K.: Modeling quality of IoT experience in autonomous vehicles. IEEE Internet Things J. **7**(5), 3833–3849 (2020)
6. Aheleroff, S., et al.: IoT-enabled smart appliances under industry 4.0: a case study. Adv. Eng. Inf. **43**, 101043 (2020)
7. Kamal, M., Srivastava, G., Tariq, M.: Blockchain-based lightweight and secured v2v communication in the internet of vehicles. IEEE Trans. Intell. Transp. Syst. (2020)
8. Yin, X.C., et al.: Toward an applied cyber security solution in IoT-based smart grids: an intrusion detection system approach. Sensors **19**(22), 4952 (2019)
9. Wan, J., et al.: Wearable IoT enabled real-time health monitoring system. EURASIP J. Wirel. Commun. Networking **298** (2018)

10. Christaki, E.: New technologies in predicting, preventing and controlling emerging infectious diseases. Virulence **6**(6), 558–565 (2015)
11. Mohammed, M.N., et al.: Novel COVID-19 detection and diagnosis system using IOT based smart helmet. Int. J. Psychosocial Rehabil. **24**(7) (2020)
12. Singh, R.P., et al.: Internet of things (IoT) applications to fight against COVID-19 pandemic. Diabetes Metab. Syndrome: Clin. Res. Rev. (2020)
13. Bai, L., et al.: Chinese experts' consensus on the Internet of Things-aided diagnosis and treatment of coronavirus disease 2019 (COVID-19). Clin. eHealth **3**, 7–15 (2020)
14. Javaid, M., et al.: Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. Diabetes Metab. Syndrome: Clin. Res. Rev. (2020)
15. Dewey, C., et al.: Supporting clinicians during the COVID-19 pandemic (2020)
16. Stoessl, A.J., Bhatia, K.P., Merello, M.: Movement disorders in the world of COVID-19. Mov. Disord. Clin. Pract. **7**(4), 355–356 (2020)
17. Maanak, G., Abdelsalam, M., Mittal, S.: Enabling and enforcing social distancing measures using smart city and its infrastructures: a COVID-19 use case. arXiv preprint arXiv:2004.09246 (2020)
18. Siriwardhana, Y., et al.: The role of 5G for digital healthcare against COVID-19 pandemic: opportunities and challenges. ICT Express (2020)
19. Kumar, U.S., Suryadevara, N.K., Udgata, S.N.: Internet of Things and Sensor Network for COVID-19 (2020)
20. Kummitha, R.K.R.: Smart technologies for fighting pandemics: the techno-and human-driven approaches in controlling the virus transmission. Government Inf. Q. 101481 (2020)
21. Siriwardhana, Y., et al.: The fight against the COVID-19 pandemic with 5G technologies. IEEE Eng. Manage. Rev. **48**(3), 72–84 (2020)
22. Joshi, A.M., Shukla, U.P., Mohanty, S.P.: Smart healthcare for diabetes during COVID-19. IEEE Consum. Electron. Mag. **10**(1), 66–71 (2020)
23. Ndiaye, M., et al.: IoT in the wake of COVID-19: a survey on contributions, challenges and evolution. IEEE Access **8**, 186821–186839 (2020)
24. Nižetić, S., et al.: Internet of things (IoT): opportunities, issues and challenges towards a smart and sustainable future. J. Cleaner Prod. **274**, 122877 (2020)
25. Kamal, M., Aljohani, A., Alanazi, E.: IoT meets COVID-19: status, challenges, and opportunities. ArXiv preprint arXiv:2007.12268 (2020)
26. Vangeti, M., et al.: Applications of internet of things (IoT) to track COVID-19 in real time. Int. J. Adv. Res. Eng. Technol. (IJARET) **11**(9) (2020)
27. Ahmad, R.W., et al.: Blockchain and COVID-19 pandemic: applications and challenges (2020)
28. Dorri, A., et al.: Blockchain for IoT security and privacy: the case study of a smart home. In: 2017 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom workshops), IEEE (2017)
29. Vijayalakshmi, R., Sengeni, D.: IOT based smart detection system for harmful gases in underground sewages (2017)
30. Aman, M.N., Chua, K.C., Sikdar, B.: Secure data provenance for the internet of things. In: Proceedings of the 3rd ACM International Workshop on IoT Privacy, Trust, and Security (2017)
31. Aman, M.N., Basheer, M.H., Sikdar, B.: Two-factor authentication for IoT with location information. IEEE Internet Things J. **6**(2), 3335–3351 (2018)
32. Kamal, M.: Lightweight security and data provenance for multi-hop internet of things. IEEE Access **6**, 34439–34448 (2018)
33. Nasajpour, M., et al.: Internet of things for current COVID-19 and future pandemics: an exploratory study. J. Healthcare Inf. Res. 1–40 (2020)
34. Haleem, A., Javaid, M., Khan, I.H.: Internet of things (IoT) applications in orthopaedics. J. Clin. Orthop. Trauma **11**, S105–S106 (2020)
35. Singh, R.P., et al.: Internet of medical things (IoMT) for orthopaedic in COVID-19 pandemic: roles, challenges, and applications. J. Clin. Orthop. Trauma (2020)

36. Rudra, B., Prashanth, D.S.: Models and algorithms for energy conservation in internet of things. Energy Conservation for IoT Devices, pp. 75–110. Springer, Singapore (2019)
37. Wang, C.J, Chun Y.N., Brook, R.H.: Response to COVID-19 in Taiwan: big data analytics, new technology, and proactive testing. JAMA **323**(14), 1341–1342 (2020)
38. Kim, R.Y.: The impact of COVID-19 on consumers: preparing for digital sales. IEEE Eng. Manage. Rev. (2020)
39. Chhetri, B., et al.: Estimating the prevalence of stress among Indian students during the COVID-19 pandemic: a cross-sectional study from India. J. Taibah Univ. Med. Sci. (2021). https://doi.org/10.1016/j.jtumed.2020.12.012
40. Baker, S.B., Xiang, W., Atkinson, I.: Internet of things for smart healthcare: technologies, challenges, and opportunities. IEEE Access **5**, 26521–26544 (2017)
41. Rao, V., Prema, K.V., Rao, S.S.: An overall perspective on establishing end-to-end security in enterprise IoT (E-IoT). Business Intelligence for Enterprise Internet of Things, pp. 81–97. Springer, Cham (2020)
42. Sethi, J.K., Mittal, M.: Monitoring the impact of air quality on the COVID-19 fatalities in Delhi, India: using machine learning techniques. Disaster Med. Pub. Health Prep. 1–8 (2020)
43. Tulshyan, V., Sharma, D., Mittal, M.: An eye on the future of COVID'19: prediction of likely positive cases and fatality in India over a 30 days horizon using prophet model. Disaster Med. Pub. Health Prep. 1–20 (2020)
44. Mittal, M., Balas, V.E., Goyal, L.M., Kumar, R. (Eds.): Big data processing using spark in cloud. Springer (2019)
45. Arora, M., et al.: Factors affecting digital education during COVID-19: a statistical modeling approach. In: 2020 5th International Conference on Computing, Communication and Security (ICCCS), IEEE (2020)
46. Ahmed, N., et al.: A survey of covid-19 contact tracing apps. IEEE Access 8134577–134601 (2020)
47. Jacob, S., Lawarée, J.: The adoption of contact tracing applications of COVID-19 by European governments. Policy Des. Pract. 1–15 (2020)
48. Gasser, U., et al.: Digital tools against COVID-19: taxonomy, ethical challenges, and navigation aid. The Lancet Digital Health (2020)
49. POSTMAN APIs—Postman COVID-19 API Resource Center | List of APIs and Blueprints. https://covid-19-apis.postman.com/
50. Alashhab, Z.R., et al.: Impact of coronavirus pandemic crisis on technologies and cloud computing applications. J. Electron. Sci. Technol. **19**, 100059 (2020)
51. Universiti Sains Malaysia (USM) COVID-19: Social responsibility, preventive policy and current developments at Universiti Sains Malaysia. https://www.usm.my/index.php/covid19/announcements/768-23-march-2020-usm-scenario-planning-for-covid-19
52. Cloud migration services market size, share and global market forecast to 2022 [Online]. Available https://www.marketsandmarkets.com/Market-Reports/cloud-migration-service-market-266815130.html (April 2020)
53. https://aws.amazon.com/solutions/case-studies/blackboard/
54. Pfleeger, C.P., Pfleeger, S.L.: Security in Computing. Prentice Hall Professional Technical Reference, Prentice-Hall (2002)
55. Coronavirus: Vodafone, O2 and other networks struggle amid huge surge in traffic [Online]. Available https://www.independent.co.uk/life-style/gadgetsand-tech/news/coronavirus-vodafone-o2-talktalk-down-outage-dataa9411286.html (April 2020)
56. Al-Sai, A.Z., Abdullah, R.: Big data impacts and challenges: a review. In: 2019 IEEE Jordan International Joint Conference on Electrical Engineering and Information Technology (JEEIT), IEEE (2019)
57. IoT use cases across Healthcare. https://zinnov.com/iot-use-cases-for-covid-19-adoption-stories-from-the-frontlines/
58. Castro, J.D.B., et al.: A free web service for fast COVID-19 classification of chest X-ray images. ArXiv preprint arXiv:2009.01657 (2020)