A Comprehensive Review of Applications of Internet of Things for Covid-19 Pandemic

S Malliga1*, S V Kogilavani2 and P S Nandhini3
1,2,3 Department of Computer Science and Engineering, Kongu Engineering College, Perundurai, Erode, Tamil Nadu – 638 060.

*Email:mallinishanth72@gmail.com

Abstract. Due to the raise of Covid-19 pandemic, there has been a surge in interest for the use of digital tools and technologies for pandemic containment While investigating, it is understood that the strategies based on potential digital technologies would definitely yield better benefits and these strategies have been recently used for controlling the pandemic In this article, we review how Internet of Things (IoT) and Sensors take health care to a new level and pioneers in addressing the Covid-19 pandemic The recent cutting-edge IoT tools play a crucial role in restraining the spread of the virus and supporting the treatment of the infected persons This survey explores the recent IoT efforts and possible scenarios for addressing various Covid-19 issues like pre-screening, tracking of infected/quarantined people and many more We also examine the research opportunities that have been opened up due the application of IoT for the management of Covid-19 crisis Further, we have also identified a few challenges and issues to be addressed while using IoT during Covid-19 pandemic

Keywords: Covid-19, Internet of Things, Sensors, IoT tools, pre-screening, tracking of quarantined persons

1. Introduction
The Internet of Things (IoT) is made up of a complex network of smart devices that exchange data using the Internet [1] It has modernized the real world objects into smart objects The objective of IoT is to help the users to control the objects around them and also keep them up-to-date about the state of the things [2] The smart IoT objects sense the environment and send the acquired data via the Internet without the requirement of human effort IoT plays a significant role in various walks of life such as healthcare systems[3], driverless vehicles [4], home and industrial automation [5], intelligent transportation [6], smart grids [7] and a lot more

Recently, novel Severe Acute Respiratory Syndrome Corona virus 2 (SARS-Covid-2) gave raise to a global pandemic infectious disease called Covid-19[8] This new virus and the disease induced by it were not known before the beginning of outbreak in Wuhan, China, during December 2019 Since then, Covid-19 has become a pandemic striking many countries globally According to the Centers for Disease Control and Prevention (CDC), person-to-person contact is identified as the main method of transmission of SARS-Covid-19 virus The society needs to keep the workplace and our surrounding healthy and thriving environment The history and timeline details of this virus can be found in [9]

In the current pandemic situation, globally there is an increase in the number of infected patients every day and a necessity to exploit the potential of IoT methodology
IoT comes up with the constituents needed to help in minimizing the effect of Covid-19 IoT has a wide range of applications which would be effective to make sure that all the guidelines of safety and precautions provided by health officials are followed [10] IoT has the potential to deal with huge amount of data received from sensors used by number of applications to fight against COVID-19 and can be a technology to ensure that all infected persons are quarantined safely IoT helps to track high risk patients easily This technology is used for the measuring blood pressure, rate of heartbeat and level of glucose [11, 12] Furthermore, IoT helps to reduce the workload and in turn, improve the efficiency of medical staff Since more number of attempts has been carried out for utilizing the potential of IoT technology, this article discusses the application of IoT tackling the COVID-19 pandemic.

The rest of the article is orchestrated as follows: In section 2, we present a brief list of applications where IoT can play a major role The recent research efforts that utilized IoT during Covid-19 crisis to bring down the issues that have been faced are explored in Section 3 Section 4 presents findings from the reviewed articles and the challenges to be addressed while utilizing this technology The conclusion is given in the Section 5.

2. Significant applications of IoT during Covid-19 pandemic
At present, it is a challenging task to detect and prevent the spreading of Corona Virus and help the medical practitioners, staff nurses and healthcare workers, etc to offer their treatments in a productive and effective manner to the patients This article investigates and presents the research activities that have been carried out using IoT to handle this pandemic in recent times The society faces many issues in this pandemic situation like maintaining social distance, availing the medical facilities, monitoring and tracking quarantined etc These issues can be addressed through IoT in an efficient manner and helps to serve the society timely and promisingly The various roles played by IoT during this pandemic are shown in Figure 1 and include

- Timely detection of the infection and diagnosis the same
- Deterrence of and controlling the spreading of infection
- Tracking the quarantined patients
- Contact tracing of infected persons
- Assisting healthcare workers
- Supply of medicines and medical equipments and food items
- Remote monitoring of patients

Figure 1 Applications of IoT during Covid-19 pandemic.
3. Role of IoT Technologies and Tools in Covid-19 Pandemic

Here, in this section, we present the attempts put through by the different research communities to tackle Covid-19 crisis using IoT tools and technologies. We also present commercially available IoT products to handle the crisis.

Covid-19 has an unprecedented impact on our society and economy. The impact of this pandemic accelerated the adoption of many digital technologies nowadays. Allied with other technologies like AI, Big data, Cloud etc, IoT, in particular, is of great use during this catastrophe. The role of IoT in healthcare is unimaginable. Let’s review the articles which illustrated how IoT is being used to monitor the pandemic.

[13] cited that quality of service to human beings can be very well enhanced by IoT. The authors quoted that IoT can very well handle the issues in drug delivery. The use of IoT in drug delivery helps to mitigate the spreading of disease especially, during the purchase of drug and in turn, helps to save the physical and human resources. The authors of [14] addressed the problems faced by orthopaedic patients in this pandemic such as availing the medical facilities, purchase of medicine etc. Internet of Medical Things (IoMT) can resolve these issues and helps the orthopaedic patients living in remote locations where it is difficult to extend the medical facilities. Javaid et al. [15] carried out a review of the technologies of Industrial IoT and their potential applications in the Covid-19 pandemic. In addition, the authors also enumerated the significant technologies of Industry 4.0 namely IoT, AI, Big data, VR etc that help in Covid-19 crisis. Telemedicine services to prevent and control the virus, prediction of outbreak and minimising or even stalling the spread of the virus, using drones for surveillance to ensure the execution of quarantine and mask-wearing etc are some of the issues that are mentioned in this attempt. The main applications of IoT in Covid-19 crisis including Internet-connected hospital, tele-health consultation, rapid screening, smart tracking of infected persons, forecasting of virus etc are presented by Singh et al. [16]. This work also summarised issues and challenges to be faced while implementing IoT for Covid-19. In the attempt [17], Cognitive Radio (CR) based IoT is utilized to mitigate the Covid-19 crisis. This work helps to keep every person to be connected and monitored.

The various applications identified by [17] include real-time tracking, remote monitoring of the patients, instant diagnosis, contact tracing, screening and surveillance, prevention and control. The security and privacy issues of using CR are also highlighted. Chamola et al. [18] highlighted the role of IoMT in monitoring patients from a remote location, tracking the order of medical items and usage of wearables to convey the health information to the officials concerned. [19] focussed on wearable devices for monitoring the quarantined patients for various parameters like oxygen saturation, respiratory rate, lung sound rate etc., a sensing systems to detect the infection and monitor patients with mild symptoms and telehealth technologies for the remote monitoring and diagnosis of Covid-19.

The work by Nasajpour et al. [20] surveyed the role of IoT-based technologies in Covid-19 outbreak and reviewed the current IoT-based solutions for combating Covid-19. They segregated the IoT solutions in three main phases namely solutions for early diagnosis, quarantine time, and after recovery. For each phase, IoT enabled devices such as IoT buttons, wearables, drones, robots and smart phone applications have also been depicted.

In the work [21-31], the authors examined the current status of IoT applications related to Covid-19, identified their deployment and operational challenges, and suggested the potential opportunities to further control the pandemic. Also, they have presented an analysis for implementing IoT in which internal and external factors have also been addressed. Apart from the research efforts that have been cited above, there are a number of IoT devices available for managing the pandemic. Some of them are presented below.

‘Suraksha Kawach’ [32] is an IoT used for tracking of corona infected patients and their surveillance and developed by Defence Research and Development organization (DRDO). India. This device can be worn in arm or ankle and it is a GSM and GPS-based device for real-time tracking. Figure 2 shows a sample Suraksha Kawach device.
To reduce the risks of healthcare workers, temperature sensors are used to measure body temperature of Covid-19 patients. Figure 3 depicts a sample temperature sensor.

Next we have wearable devices. These devices measure different parameters like temperature, heart rate, pulse rate, etc and the measured values can be used for taking actions at the earliest. These devices play a significant role in the containment of Covid-19. Smartband is one such wearable device and is shown in Figure 4.

IoT buttons are also IoT devices that help to manage diagnosis better and faster. In Canada, IoT buttons were deployed to clean hospitals and are used to alert the officials in case of any concerns related to sanitation and public safety. The AWS IoT Button is another programmable button that can be used to count or track items, call or alert, order service, etc. For instance, the IoT button can be...
programmed to alert if there is a need to clean any hospital restrooms and then receive response from maintenance personals after cleaning the restrooms Examples of IoT buttons are shown in Figure 5

![Figure 5 IoT Buttons](https://www.geospatialworld.net/blogs/how-iot-can-help-fight-Covid-19-battle/)

Here, we consolidate all the recent research efforts on tackling Covid-19 pandemic using IoT and present their role in fighting against the Covid-19 pandemic in Table 1.

| Authors          | Year | Role played by the technology in addressing the Covid-19 pandemic                                                                 |
|------------------|------|-------------------------------------------------------------------------------------------------------------------------------|
| Rajvikram et al  | 2020 | 1. Prediction and forecasting the infection rate, diagnosis of disease<br>2. Providing quality healthcare services (e.g. Drug delivery at home)<br>3. Transportation of goods and surveillance, reducing labor intensive work like nursing, monitoring the infected persons<br>4. Providing clinical assistance anywhere, anytime |
| Pratap et al     | 2020 | 1. Remote monitoring of orthopaedic patients                                                                                   |
| Javaid et al     | 2020 | 1. Telemedicine service to prevent the infection and control the spreading of virus<br>2. Predicting the outbreak and minimising or even stalling the spread of the virus<br>3. Surveillance of quarantine persons and to ensure mask-wearing |
| Pratap et al     | 2020 | 1. Internet-connected hospital<br>2. Tele-health consultation<br>3. Rapid screening<br>4. Smart tracking of infected persons<br>5. Forecasting of virus<br>6. Actual and live information about the spread of the infection |
| Mohanty et al    | 2020 | 1. Real-time tracking<br>2. Remote monitoring of the patient<br>3. quick and instant diagnosis<br>4. Contact tracing<br>5. Screening and surveillance<br>6. Prevention and control of spread of disease |
| Chamola et al    | 2020 | 1. Remote monitoring of patients<br>2. Tracking the orders of medical items<br>3. Wearables to convey health information to the concerned health care officials |
4. Disease Surveillance and risk prediction, medical diagnosis, screening, therapeutic Research  
5. Treatment of patients, and reduce the stress levels of the frontline healthcare workers  
6. Robot-controlled disinfection methods  
7. Contact tracing  
8. Facilitating increased testing and reporting  
9. Secure donation platform for donors  
10. Controlling supply chain disruptions and issues  
11. Secured recording of patients’ details  
12. Data collection and analysis about the spread of virus  

| Nasajpour et al [20] | 2020 | 1. Early diagnosis, quarantine time, and after recovery |
|----------------------|------|------------------------------------------------------|
| Mohsin Kamal et al [21] | 2020 | 1. Deployment and operational challenges, and suggested the potential opportunities to further control the pandemic  
2. IoT enabled ambulances, Smart health monitoring gadgets  
3. AI based forecasting and social distancing  
4. virtual education and conferencing |
| Maria Tsikala Vafea [22] | 2020 | 1. Predict the rate of Covid-19 infections to find the mortality risk of a person with Covid-19  
2. Predict and help to identify critically ill patients at the earliest possible  
3. Perform effective therapeutic strategies  
4. Record and monitor temperature measurements of patients with Covid-19  
5. Distribute medical items and test kits to the areas that are difficult to reach |
| Rahman et al [23] | 2020 | 1. Real-time surveillance using wearable health-monitoring devices  
2. Cloud-based remote health testing  
3. Real time analysis of data  
4. Using the travel history data to quickly diagnose infected patients and predict the possible spread of a disease to other locations |
| Bai et al [24] | 2020 | 1. Developed an Intelligent Diagnosis and Treatment Assistant Program (nCapp) based on the IoT medical technology to conduct clinical work during the Covid-19 pandemic  
2. Assisting the diagnosis and treatment, early identification, isolation, and treatment of patients with COVID-19 |
| Kumbhar et al [25] | 2020 | 1. Detection of social distance breaches using CNN  
2. Area-based tracking based on the user cellular activities  
3. Detection of infected persons in an area  
4. Identification of severely symptomatic person using wearable devices  
5. Contact tracing of persons in the areas at risk  
6. Timely actions and warnings for isolation |
| Yang et al [26] | 2020 | 1. Implemented point-of-care (POC) diagnostics and the IoMT to create a platform to help patients receive proper healthcare at home and establish a disease management database for government and healthcare organizations  
2. Monitoring the disease status and providing proper medical care without spreading the viral infection to others |
| Singh et al [27] | 2020 | 1. Designed an IoT based wearable quarantine band to detect and track the persons who abscond in real time |
| Lin and Wu [28] | 2020 | 1. Effective distribution of the much-needed medication items  
2. Tracking of production and demands for medical supplies |
| Garg et al [29] | 2020 | 1. Digital enabled contact tracing, technologies, usage, and network options |
Kumar et al [30] 2020
1. Smart sensors to measure and record the body temperature of individuals to identify the infected persons
2. Cloud computing and data analysis to make an effective decision based on real-time data

Otoom et al [31] 2020
1. Early Identification or Prediction of COVID-19 cases
2. Real-time Monitoring of COVID-19
3. Treatment Response of COVID-19 confirmed cases
4. An IoT-based Framework for COVID-19

4. Findings and discussions
A number of new technological trends have made a difference in the battle against Covid-19. They include AI, ML, DL, IoT, 5G, Big data, Robots, Drone, Blockchain. This study reviewed the recent research activities which explored IoT to fight against the war of Covid-19 and alleviate its impact. Considering those technologies as the foundation of this review, in this section, we recommend some of the insights on the utilization of IoT further to manage this Covid-19 pandemic.

In spite of its usefulness in Covid-19 pandemic, IoT faces many challenges when using it for containment of Covid-19. A few of them are described below:

IoT encompasses a myriad number of interconnected sensors and devices to establish a smart system for the effective containment of Covid-19 crisis. As the number of IoT devices in IoMT increases exponentially, scalability is a big challenge in this pandemic. The scalability, in turn, increases the energy requirements of these devices.

Since the number of IoT devices is increasing, high bandwidth is required to transmit all the information from sensors to the cloud. Currently, IoT devices use 4G/LTE networks to perform their tasks. Soon after the use of 5G, this problem could be easily overcome.

The next issue that may be considered for further exploration is the privacy and security of the data generated by a huge number of devices. As we are aware that, the IoT devices have constraints like low power and less computational speed, the traditional encryption algorithms like DES, 3DES, and AES seem not feasible for IoT devices. Hence, the security algorithms should be energy efficient and shall have low computational complexities to offer data security and privacy. This motivates the researchers to design lightweight security solutions for IoT devices. Due to the outbreak of Covid-19, the security requirements of IoT devices got increased and some of them are:

i. The data like temperature, heart rate, pulse rate etc. sensed from the Corona infected persons should be accurate and secured
ii. No forgery of data
iii. No interception of data during its transmission

The above research issues may be addressed in future.

5. Conclusion
Covid-19 is an infectious disease and a global pandemic. This deadly disease has set off an unprecedented demand for IoT solutions and has given away successful solutions such as early detection of the infection and diagnosis of the infection, monitoring the treatment and quarantined persons, contact tracing, estimate of rate of cases and mortality, assisting the healthcare workers etc.

The applications of IoT to fight against this global pandemic can be extended to several sectors like healthcare, logistics etc which play a key role in reducing the risk of corona virus outbreak. In this study, we have reviewed the articles that investigated the role of IoT in this crisis and presented how they helped.
In addition, we have also identified a few research issues after reviewing the recent attempts which include ensuring accuracy, security and impersonation and confidentiality of the data generated by IoT devices.

To summarize, while the world continues to depend on traditional healthcare measures for addressing the Covid-19 pandemic, but in 2020, there is now a broad range of IoT tools and technologies that can be used to improve the present public-health scenario.

References

[1] Srinivasan C A review on the different types of Internet of Things (IoT) Journal of Advanced Research in Dynamical, 2019 11(1): p 154-158
[2] Alfonso Panarello, Nachiket Tapas, Giovanni Merlino, Francesco Longo, and Antonio Puliafito Blockchain and IoT integration: A systematic survey Sensors, 2018 18(8): p 2575
[3] Durga Saranya K, Krishnamurthy R, Srinivas KNH, Sarveswara Rao and Amiri I S IoT-Based Health Monitoring System Using BeagleBone Black with Optical Sensor Journal of Optical Communications, 2019 1(ahead-of-print)
[4] Minovski D, Ahlund C and Mitra K Modeling Quality of IoT Experience in Autonomous Vehicles IEEE Internet of Things Journal, 2020 7(5): p 3833-3849
[5] Shohin Aheleroff, Xin Xu, Yaqian Lu, Mauricio Aristizabal, Juan Pablo Velásquez, Benjamin Joa, and Yesid Valencia IoT-enabled smart appliances under industry 40: A case study Advanced Engineering Informatics, 2020 43: p 101043
[6] Mohsin Kamal, Gautam Srivastava, and Muhammad Tariq Blockchain-Based Lightweight and Secure V2V Communication in the Internet of Vehicles IEEE Transactions on Intelligent Transportation Systems, 2020
[7] Xiao Chun Yin, Zeng Guang Liu, Lewis Nkenyereye, and Bruce Ndibanje Toward an Applied Cyber Security Solution in IoT-Based Smart Grids: An Intrusion Detection System Approach Sensors, 2019 19(22): p 4952
[8] Whitelaw S et. al. Applications of digital technology in COVID-19 pandemic planning and response The Lancet Digital Health, 2020
[9] Alam T J A Coronavirus Disease (Covid-19): Reviews, Applications, and Current Status Current Status, 2020
[10] Quoc-Viet Pham, Dinh C Nguyen, Won-Joo Hwang and Pubudu N Pathirana, Artificial Intelligence (AI) and Big Data for Coronavirus (COVID-19) Pandemic: A Survey on the State-of-the-Arts 2020
[11] Mohammed M N, Syamsudin H, Al-Zubaidi S, Ramli R and Yusuf E Novel COVID-19 detection and diagnosis system using IOT based smart helmet International Journal of Psychosocial Rehabilitation, 2020 24(7)
[12] Vaishya R, Javaid M, Khan I H and Haleem A Artificial Intelligence (AI) applications for COVID-19 pandemic Diabetes Metabolic Syndrome: Clinical Research, 2020
[13] Elavarasan R M and Pugazhendhi R Restructured society and environment: A review on potential technological strategies to control the COVID-19 pandemic Science of The Total Environment, 2020: p 138858
[14] Ravi Pratap Singh, Mohd Javaid, Abid Haleem, Raju Vaishya and ShokatAli Internet of Medical Things (IoMT) for orthopaedic in COVID-19 pandemic: Roles, challenges, and applications Journal of Clinical Orthopaedics, 2020
[15] Mohd Javaid , Abid Haleem, Raju Vaishya, Shashi Bahl, Rajiv Suman and Abhishek Vaish Industry 40 technologies and their applications in fighting COVID-19 pandemic Diabetes Metabolic Syndrome: Clinical Research, 2020
[16] Ravi PratapSingh, MohdJavaid, AbidHaleem and RajivSuman Internet of things (IoT) applications to fight against COVID-19 pandemic Diabetes Metabolic Syndrome: Clinical Research, 2020
[17] Swayamsiddha S and Mohanty C Reviews, Application of cognitive Internet of Medical Things for COVID-19 pandemic Diabetes Metabolic Syndrome: Clinical Research, 2020

[18] Vinay Chamola, Vikas Hassija, Vatsal Gupta and Mohsen Guizani A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact IEEE Access, 2020 8: p 90225-90265

[19] Ding X R et. al. Wearable Sensing and Telehealth Technology with Potential Applications in the Coronavirus Pandemic IEEE Reviews in Biomedical Engineering, 2020

[20] Mohammad Nasajpour, Seyedamin Pouriyeh, Reza M. Parizi, Mohsen Dorodchi, Maria Valero and Hamid R. Arabnia Internet of Things for Current COVID-19 and Future Pandemics: An Exploratory Study arXiv preprint arXiv:11147, 2020

[21] Kamal M A, Aljohani and Alanazi E IoT meets COVID-19: Status, Challenges, and Opportunities arXiv preprint arXiv:12268, 2020

[22] Maria Tsikala-Vafea, Eleftheria Atalla,Joanna Georgakas,Fadi Shehadeh, Evangelia K. and Mylona Markos Kalligeros Emerging Technologies for Use in the Study, Diagnosis, and Treatment of Patients with COVID-19 Cellular molecular bioengineering, 2020: p 1-9

[23] Md Siddikur Rahman, Noah C Peeri, Nistha Shrestha, Rafdzah Zaki, Ubydul Haque, Siti Hafizah Ab Hamid Defending against the Novel Coronavirus (COVID-19) Outbreak: How Can the Internet of Things (IoT) help to save the World? Health Policy Technology, 2020

[24] Bai L et. al. Chinese experts’ consensus on the Internet of Things-aided diagnosis and treatment of coronavirus disease 2019 (COVID-19) J Clinical eHealth, 2020 3: p 7-15

[25] Hassan Kumbhar F, Hassan S A and Shin New Normal: Cooperative Paradigm for Covid-19 Timely Detection and Containment using Internet of Things and Deep Learning arXiv e-prints, 2020: p arXiv: 200812103

[26] Ting Yang, Mattia Gentile, Ching-Fen Shen and Chao-Min Cheng Combining point-of-care diagnostics and internet of medical things (IoMT) to combat the COVID-19 pandemic 2020, Multidisciplinary Digital Publishing Institute

[27] Vibhutesh Kumar Singh, Himanshu Chandna, Ashish Kumar, Sujeet Kumar, Nidhi Upadhyay and Kumar Utkarsh IoT-Q-Band: A low cost internet of things based wearable band to detect and track absconding COVID-19 quarantine subjects EAI Endorsed Transactions on Internet of Things, 2020 6(21)

[28] Lin B and Wu S COVID-19 (Coronavirus Disease 2019): Opportunities and challenges for digital health and the internet of medical things in China OMICS: A Journal of Integrative Biology, 2020 24(5): p 231-232

[29] Lalit Garg, Emeka Chukwu, Nidal Nasser, Chinnay Chakraborty and Gaurav Garg Anonymity preserving IoT-based COVID-19 and other infectious disease contact tracing model 2020 pp 159402-159414

[30] Kumar K, Kumar N and Shah Role of IoT to avoid spreading of COVID-19 International Journal of Intelligent Networks 2020 pp 32-35

[31] MwaffaqOtoum, NesreenOtoum, Mohammad A.Alzubaidi, YousefEtoom and RudainaBanihani An IoT-based framework for early identification and monitoring of COVID-19 cases Bio Medical Signal Processing and Control 2020 62: pp 1-9

[32] Gore M M Role of India's Technological Innovations to Mitigate Covid-19 Pandemic Journal of Indian Research 2020 8(1): p 11-20