



Contents lists available at ScienceDirect

Diabetes & Metabolic Syndrome: Clinical Research & Reviews

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

Internet of things (IoT) applications to fight against COVID-19 pandemic

Ravi Pratap Singh^a, Mohd Javaid^{b,*}, Abid Haleem^b, Rajiv Suman^c^a Department of Industrial and Production Engineering, Dr B R Ambedkar National Institute of Technology, Jalandhar, Punjab, India^b Department of Mechanical Engineering, Jamia Millia Islamia, New Delhi, India^c Department of Industrial & Production Engineering, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, India

ARTICLE INFO

Article history:

Received 23 April 2020

Received in revised form

27 April 2020

Accepted 27 April 2020

Keywords:

Coronavirus

COVID-19

Internet of things

IoT applications

Pandemic

ABSTRACT

Background and aim: The current global challenge of COVID-19 pandemic has surpassed the provincial, radical, conceptual, spiritual, social, and pedagogical boundaries. Internet of Things (IoT) enabled healthcare system is useful for proper monitoring of COVID-19 patients, by employing an interconnected network. This technology helps to increase patient satisfaction and reduces readmission rate in the hospital.

Methods: Searched the databases of Google Scholar, PubMed, SCOPUS and ResearchGate using the keywords “Internet of things” or “IoT” and “COVID-19”. Further inputs are also taken from blogs and relevant reports.

Results: IoT implementation impacts on reducing healthcare cost and improve treatment outcome of the infected patient. Therefore, this present study based research is attempted to explore, discuss, and highlight the overall applications of the well-proven IoT philosophy by offering a perspective roadmap to tackle the COVID-19 pandemic. Finally, twelve significant applications of IoT are identified and discussed. It has ultimately forced the researchers, academicians, and scientists to propose some productive solutions to overcome or confront this pandemic.

Conclusions: IoT is helpful for an infected patient of COVID-19 to identify symptoms and provides better treatment rapidly. It is useful for patient, physician, surgeon and hospital management system.

© 2020 Diabetes India. Published by Elsevier Ltd. All rights reserved.

1. Introduction

The Internet of Things (IoT) is a well-defined scheme of interconnected computing tactics, digital, and mechanical devices possessing the capability of transmission of data over the defined network without having any human involvement at any level. All these discussed devices are associated with their particular unique identification numbers or codes. IoT is now well established and proven technology which acts as a junction to the umpteen tactics, instantaneous analytics, philosophy of machine learning, sensory products, etc. Moreover, IoT in typical daily functioning is recognised as the utility of the products or the appliances serve the real-life requirements of human beings in various means such as;

security system of the home, smart lighting arrangements, and many more others which is easily controllable through our daily using smart speakers, smartphones, etc. [1,2].

In the present pandemic situation, all the countries, including India, are fighting with COVID-19 and still looking for a practical and cost-effective solution to face the problems arising in several ways. Researchers in physical sciences and engineering are attempting to take such challenges, to grow new theories, to describe new study problems, to generate user-centred explanations, and to edify ourselves and the overall civilian. This brief review has aimed to provide awareness of this innovative technology and its significant applications for COVID-19 pandemic.

2. IoT and its background for COVID-19 pandemic

In straightforward words, the Internet of Things (IoT) is the system of interconnected devices/operations complied with all the network elements such as; hardware, software, connectivity of the network, and any other required electronic/computer means that

* Corresponding author.

E-mail addresses: singhrp@nitj.ac.in (R.P. Singh), mjavaid@jmi.ac.in (M. Javaid), ahaleem@jmi.ac.in, haleem.abid@gmail.com (A. Haleem), raje.suman@gmail.com (R. Suman).

ultimately makes them responsive by supporting in data alteration and collection. If we talk a bit more about IoT, it is beyond to a concept that develops the overall architectural background which ultimately allows the integration and the effective exchange of the data between the person in need and the service providers. In the present typical situation, most of the problems are arising because the non-effective reachability to the patients, which is the second most considerable issue after the concern of vaccine development [3,4]. The use of the IoT concept makes the reachability to the patients quite useful, which ultimately help to provide them with significant care so that they can get out of this disease.

3. Need for the study

In the problematic current pandemic situation, the number of infected patients is increasing day by day globally, and there is a vast need to utilise the well adequate and organised facilities offered with the Internet of Things methodology. Furthermore, IoT has already been employed to serve the asked purposes in different domains in which the Internet of Healthcare Things (IoHT) or Internet of Medical Things (IoMT) are associated with the present issues. By following up the guidelines and the facilities of IoHT/IoMT, the number of resolved cases can be enhanced and improved too.

4. Key merits of IoT for COVID-19 pandemic

IoT is an innovative technology which ensures that all infected persons due to this virus are quarantine. During quarantine, it is helpful for a proper monitoring system. All high-risk patients are tracked easily using the internet-based network. This technology is used for the biometric measurements like blood pressure, heart-beat and glucose level [5,6]. Fig. 1 shows the critical merits of IoT for COVID-19 Pandemic.

With the successful implementation of this technology, we can see an improvement in the efficiency of medical staff with a reduction in their workload. The same can be applicable in the case of COVID-19 pandemic with lesser expenses and mistakes.

5. Processes involved in IoT for COVID-19

IoT is an innovative technological platform to fight with COVID-19 pandemic and can fulfil significant challenges during the lockdown

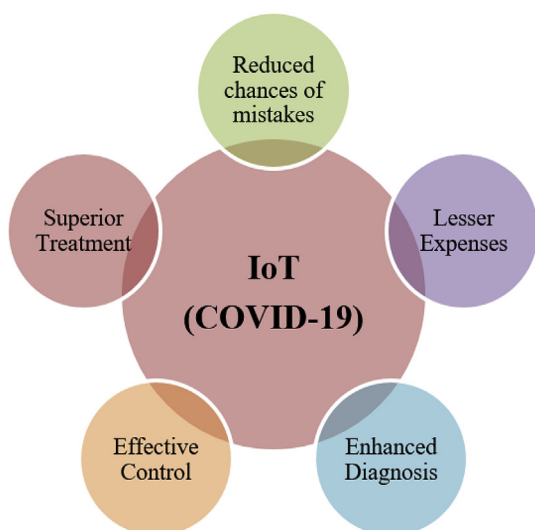


Fig. 1. Major key-merits of using IoT for fighting COVID-19 pandemic.

situation. This technology is helpful to capture the real-time data and other necessary information of the infected patient [7–9]. Fig. 2 shows the significant processes used by IoT for COVID-19.

In the first step, IoT is used to capture health data from various locations of the infected patient and manage all the data using the virtual management system [10,11]. This technology helps control the data and follow up on the report attained.

6. The overall impact of IoT in context to COVID-19 concerns (i.e. contact tracing, cluster identification and compliance of quarantine)

As discussed, the internet of things concept utilises the inter-connected network for the effective flow and exchange of data. It also enables the social workers, patients, civilians, etc. to be in connection with the service benefactors for discussing any issue and cooperation. Therefore, by employing the proposed IoT tactic in COVID-19 pandemic, the effective tracing of the patients, as well as the suspicious cases, can be completely assured. The symptoms related to the coronavirus are now known to most of them, civilians. By developing a well-informed group of a connected network, the identification of the cluster can be made out significantly. Some particular smartphone-based application can also be developed so that the needy ones can get benefitted out of it [12–15]. The proper reporting of the symptoms and the recovery must be up-to-date to the controller, i.e. doctors, physicians, caretakers, etc. so that the impressive move can be opted out to optimise the overall quarantine period.

7. Global technological advancements to resolve COVID-19 cases rapidly

Thus, to overcome and make the civilians more aware about the COVID-19 pandemic, the government of India has launched a smartphone application named as – ArogyaSetu, which is aimed to develop a connection between the important possible healthcare services and the people of India. Similarly, in China, the mobile application called as – Close Contact (English translation) is launched for its civilians. This application tells the app holder about the closeness to the corona-positive person. So that the extra care can be taken while moving outside. USA government is soon going to launch a similar kind of mobile application for its civilians at the end of April 2020.

After China, Taiwan was the most predictable to have more number of cases of COVID-19. However, Taiwan quickly militarised and instituted specific methodologies for any possible coronavirus case identification, suppression, and resource provision to guard the health of the community. Taiwan provided and integrated its national health insurance database with its immigration department and took catalogue to instigate the creation of big data for analytics; it generated real-time warnings during a clinical visit based on travel antiquity and medical symptoms to aid case identification. They have also made use of this latest technology, which includes scanning of QR code, connected reporting of transport history, etc. for the possible identification of the infected ones [16].

8. Significant applications of IoT for COVID-19 pandemic

IoT uses a large number of interconnected devices to create a smart network for the proper health management system. It alerts and tracks any types of diseases to improve the safety of the patient. It digitally captures the data and information of the patient without any human interaction. This data is also helpful for appropriate decision-making process [17–21]. Table 1 discusses the major applications of IoT for COVID-19 pandemic.

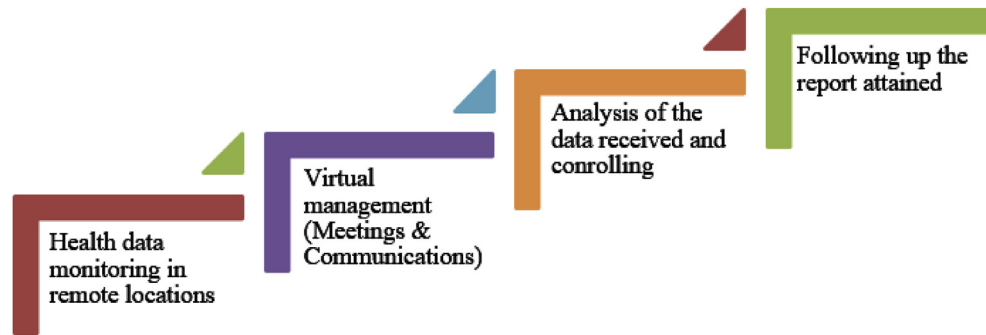


Fig. 2. Step-up Process chart for executing IoT for fighting COVID-19 pandemic.

Table 1

Major applications of IoT for COVID-19 pandemic.

SNo	Applications	Description
1	Internet-connected hospital	The implementation of IoT to support pandemic like COVID-19 needs a complete integrated network within hospital premises
2	Inform the concerned medical staff during any emergency	This integrated network will allow the patients and the staffs to respond more quickly and effectively whenever needed
3	Transparent COVID-19 treatment	The patients can avail the benefits offered without any partiality and favours
4	Automated treatment process	The selection of treatment methods become productive and helps the appropriate handling of the cases
5	Telehealth consultation	This especially makes the treatment available for the needy ones in the remote locations via employing the well-connected teleservices
6	Wireless healthcare network to identify COVID-19 patient	Various authentic applications can be installed into smartphones, which can make the identification procedure smoother and more fruitful
7	Smart tracing of infected patients	The impactful tracing of patients ultimately strengthened the service providers to handle the cases more smartly
8	Real-time information during the spread of this infection	As the devices, locations, channels, etc. are well informed and connected, the on-time information sharing can be done, and cases can be handled accurately
9	Rapid COVID-19 screening	As the case arrived/found at first instance, the proper diagnosis will be attempted through smart connected treatment devices. This ultimately makes the overall screening process more superior
10	Identify innovative solution	The overall quality of supervision is the utmost goal. It can be achieved by making innovations successful to the ground level.
11	Connect all medical tools and devices through the internet	During COVID-19 treatment, IoT connected all medical tools and devices through internet which convey the real-time information during treatment
12	Accurate forecasting of virus	Based on the data report available, the use of some statistical method can also help to predict the situation in the coming times. It will also help to plan the government, doctors, academicians, etc. to plan for a better working environment.

IoT is used for various applications to fulfil the important requirement of alleviating effects of COVID-19 pandemic. It has the capability to predict the upcoming situation with the help of appropriate captured data. Its applications are applied for proper management of this pandemic. The patient can use IoT services for proper monitoring of heart rate, blood pressure, glucometer and other activities for personalised attention. It helps to track the health conditions of older people. The significant applications of this technology in healthcare are to track the real-time location of medical equipment and devices for smooth treatment process without any delay. Healthcare insurance companies can use this technology to detect fraud claim and provide transparency in the overall system. This improves treatment workflow of the patient with efficient performance and also helpful for decision-making process during complex cases.

9. Various issues and future scope of the study

The primary point of concern while employing the Internet of Things in the present pandemic situation COVID-19 is about the security and privacy of the data received, which is unique and imperative from patient health point-of-view. The second thing is about the care to taken while integrating the data network among the devices involved and protocols. Fig. 3 depicts the summarised view of issues and challenges in implementing IoT for COVID-19 pandemic.

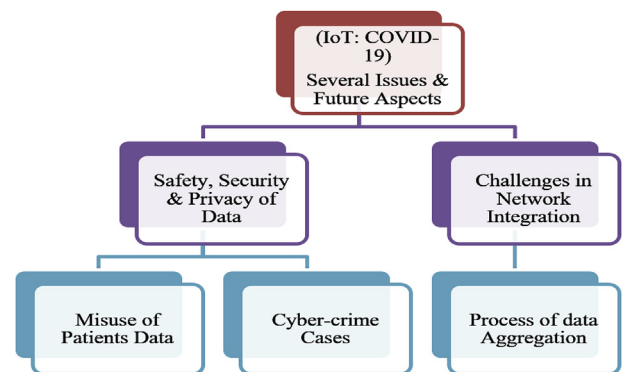


Fig. 3. Summarised view of issues and challenges in implementing IoT for COVID-19.

Moreover, future work should be targeted over data storage and management. The process of making cost-effective adoption applications will also to be considered in further studies.

10. Conclusion

IoT provides an extensive integrated network for healthcare to fight with COVID-19 pandemic. All medical devices are connected to the internet, and during any critical situation, it automatically

conveys a message to the medical staff. Infected cases can be handled appropriately in a remote location with well-connected tele-devices. It handles all cases smartly to provide ultimately strengthened service to the patient and healthcare. IoT seems to be an excellent way to screen the infected patient. In healthcare, this technology is helpful to maintain quality supervision with real-time information. By using a statistical-based method, IoT gets helpful to predict an upcoming situation of this disease. With proper implementation of this technology, researcher, doctors, government, academicians can create a better environment to fight with this disease.

Declaration of competing interest

None.

References

- [1] Haleem A, Javaid M, Khan IH. Internet of things (IoT) applications in orthopaedics. *J. Clin. Orthop.Trauma* 2019. <https://doi.org/10.1016/j.jcot.2019.07.003>. In press.
- [2] Bai L, Yang D, Wang X, Tong L, Zhu X, Bai C, et al. Chinese experts' consensus on the Internet of Things-aided diagnosis and treatment of coronavirus disease 2019. *Clinical eHealth* 2020 Mar 17. In press.
- [3] Wang Y, Hu M, Li Q, Zhang XP, Zhai G, Yao N. Abnormal respiratory patterns classifier may contribute to large-scale screening of people infected with COVID-19 in an accurate and unobtrusive manner. *arXiv preprint arXiv: 2002.05534*. 2020 Feb 12.
- [4] Haleem A, Javaid M, Vaishya R, Deshmukh SG. Areas of academic research with the impact of COVID-19. *AJEM (Am J Emerg Med)* 2020. <https://doi.org/10.1016/j.ajem.2020.04.022>. In press.
- [5] Mohammed MN, Syamsudin H, Al-Zubaidi S, A K S, Ramli R, Yusuf E. Novel COVID-19 detection and diagnosis system using IOT based smart helmet. *Int J Psychosoc Rehabil* 2020;24(7).
- [6] Vaishya R, Javaid M, Khan IH, Haleem A. Artificial Intelligence (AI) applications for COVID-19 pandemic. *Diabetes & metabolic syndrome. Clinical Research & Reviews*; 2020. <https://doi.org/10.1016/j.dsx.2020.04.012>.
- [7] Javaid M, Vaishya R, Bahl S, Suman R, Vaish A. Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. *Diabetes & metabolic syndrome. Clinical Research & Reviews*; 2020. <https://doi.org/10.1016/j.dsx.2020.04.032>.
- [8] Allam Z, Jones DS. On the coronavirus (COVID-19) outbreak and the smart city network: universal data sharing standards coupled with artificial intelligence (AI) to benefit urban health monitoring and management. *Healthcare* 2020 Mar;8(No. 1):46. Multidisciplinary Digital Publishing Institute.
- [9] Dewey C, Hingle S, Goelz E, Linzer M. Supporting clinicians during the COVID-19 pandemic. *Ann Intern Med* 2020 Mar 20. In press.
- [10] Stoessl AJ, Bhatia KP, Merello M. Movement disorders in the world of COVID-19. *Mov.Disord.Clin. Pract.* 2020 Apr 6 In press.
- [11] Gupta M, 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 Apr 13.
- [12] Inn TL. Smart city technologies take on COVID-19. *World Health*; 2020 Jan 9.
- [13] Hanna TP, Evans GA, Booth CM. Cancer, COVID-19 and the precautionary principle: prioritising treatment during a global pandemic. *Nat Rev Clin Oncol* 2020 Apr 2:1–3.
- [14] Roy D, Tripathy S, Kar SK, Sharma N, Verma SK, Kaushal V. Study of knowledge, attitude, anxiety & perceived mental healthcare need in Indian population during COVID-19 pandemic. *Asian Journal of Psychiatry* 2020 Apr 8: 102083.
- [15] Wong TY, Bandello F. Academic ophthalmology during and after the COVID-19 pandemic. *Ophthalmology* 2020. <https://doi.org/10.1016/j.ophtha.2020.04.029>. In press.
- [16] Wang CJ, Ng CY, Brook RH. Response to COVID-19 in Taiwan: big data analytics, new technology, and proactive testing. *J Am Med Assoc* 2020;323(14): 1341–2.
- [17] Zheng SQ, Yang L, Zhou PX, Li HB, Liu F, Zhao RS. Recommendations and guidance for providing pharmaceutical care services during COVID-19 pandemic: a China perspective. *Research in social and administrative pharmacy*. 2020 Mar 26.
- [18] Yang T, Gentile M, Shen CF, Cheng CM. Combining point-of-care diagnostics and internet of medical things (IoMT) to combat the COVID-19 pandemic. *Diagnostics* 2020. <https://doi.org/10.3390/diagnostics10040224>. In press.
- [19] Gupta R, Misra A. Contentious issues and evolving concepts in the clinical presentation and management of patients with COVID-19 infection with reference to use of therapeutic and other drugs used in Co-morbid diseases (hypertension, diabetes etc.). *Diabetes & metabolic syndrome. Clin Res Rev* 2020;14(3):251–4.
- [20] Gupta R, Ghosh A, Singh AK, Misra A. Clinical considerations for patients with diabetes in times of COVID-19 epidemic. *Diabetes & Metabolic Syndrome. Clin Res Rev* 2020;14(3):211–2.
- [21] Ghosh A, Gupta R, Misra A. Telemedicine for diabetes care in India during COVID19 pandemic and national lockdown period: guidelines for physicians. *Diabetes & Metabolic Syndrome: Clin Res Rev* 2020;14(4):273–6.