Internet of Things Driven Smart Cities in Post Pandemic Era

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Abstract

The rise of the Internet of Things (IoT) driven smart cities is progressively revolutionizing different aspects of human life, including transportation, communication, health, automotive and security. Several IoT initiatives and experimental setting have been proposed in recent years to establish digital and smart infrastructures. Despite the hype, the COVID-19 pandemic still has an impact on many aspects of urban life, raising concerns about the viability of past and contemporary patterns of urban design and growth. The COVID-19 epidemic has significantly altered everyday lives, damaged the economy of several countries, affected global economic goals, and so on. In such cases, it is highly required to initiate a research discussion on the influence of COVID-19 in smart cities. Several researchers and policymakers have previously recognized the need for improved smart city infrastructure. This research study reviews the multiple research discussions that design and develop new urban planning and smart city design paradigms and models in the post-COVID period that reflect the insights gained from the pandemic. The study also discussed how smart cities innovation, operations, and preventive maintenance will be influenced after COVID-19. Finally, the proposed study concluded that the smarter cities equipped with IoT driven technologies will be able to prevent pandemics in the near future.

Keywords: Smart Cities, COVID-19, Internet of Things, Healthcare, Predictive Analytics, Decision-support systems

1. Introduction

The population of India has been gradually increasing throughout the years. In this context, cities and urban area management and monitoring are currently at the top of the discussion, providing possibilities for research initiatives, technology acquisition, and

DOI: https://doi.org/10.36548/jsws.2022.1.003
Received: 10.04.2022, received in revised form: 08.05.2022, accepted: 19.05.2022, published: 30.05.2022

innovation [2]. The need for managing the cities intelligently due to the restrictions imposed by increasing population, mobility, environmental demands, health and well-being, ageing, safety, employment, and many other factors are increasing at an unprecedented rate. [1] Smart Cities employ many forms of electronic data collecting sensors and systems to provide information that would be used to efficiently manage different assets and resources. This ranges from raw sensor data to information collected from social networks. It is crucial to highlight that all of these data and information sources must be merged to provide a meaningful knowledge for smart city governance, in order to efficiently manage different factors such as healthcare, environmental quality, and mobility among others.

The emergence of Internet of Things (IoT) has enabled the development of networks of physical devices such as vehicles, household appliances, wearable devices, and other items embedded with electronics/computers, applications, sensors, and actuators that allow such objects to communicate and exchange data [3]. Smart cities collect and analyse data using IoT devices such as connected/networked sensors, lighting, and metres. Smart cities then utilize this information to enhance infrastructure, public utilities, services, and so on.

Some of the well-known examples of IoT-enabled smart city governance are:

- Live video surveillance and its analytics
- Traffic monitoring and analysis
- Connected and automated lighting and transport systems
- Smart infrastructure
- Remote health monitoring and wearable devices.

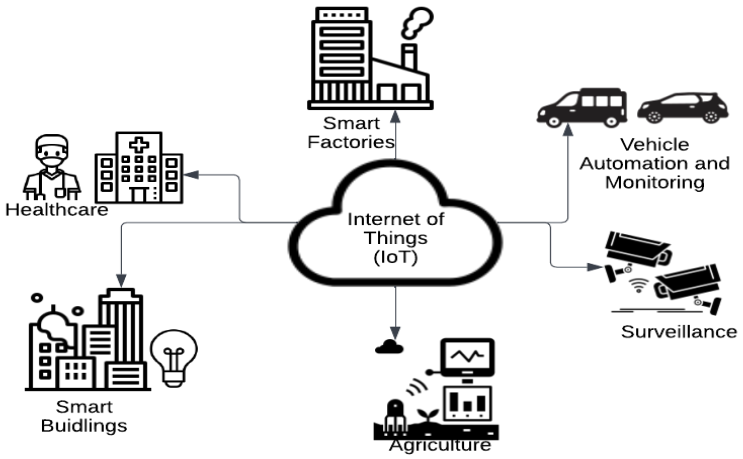

Figure 1. IoT Driven Smart City Applications

2. Research Issues & Objective

The primary goal of smart city initiatives is to effectively manage resources and improve the quality of human lives. This effort is especially important during the COVID-19 outbreak, as the situation witness a worldwide environmental, social, economic, and political crisis.

2.1 COVID-19

Coronavirus is initially disseminated by birds, pigs, rats, bats, and cats. A new beta coronavirus infected nearly 7500 people and recorded 754 fatalities in 36 different countries in November 2002. In 2012, Saudi Arabia discovered the Middle East Respiratory Syndrome (MERS) coronavirus (MERS-CoV), making it the coronavirus family's seventh member. In 2018, the coronavirus HKU2 from bat origin was responsible for acute diarrhoea disorder in pigs. COVID-2019 is closely related to other beta coronaviruses originated from bats.

With its highly contagious nature, it is critical to prevent and limit the transmission mechanism of novel Coronavirus-2019 [nCoV-2019]. Though the exact process of disease transmission remains unknown, research studies have shown that the dissemination of respiratory droplets is the primary cause of infection transfer. Non-living infected surfaces (especially plastic and steel material) are the places where the virus can live for up to 3 days [4]. The infection transmission occurs if a person comes into direct or indirect contact with the infected materials. Once the infection enters the human body, the virus moves through the nasal channel, mucus membranes and up to the breathing tubes, lungs, and air sacs of the recipient.

2.2 Smart Cities and COVID-19 Crisis Management

When a pandemic strikes a city, the role of many social bodies such as the government, healthcare, public and industry is crucial, and each of the group impacts the efficacy of a pandemic response. To combat the unexpected pandemic outbreak like COVID-19 [5], the interrelationships between the technologies and people must be strengthened. This makes it critical for everyone to seek answers on the different views of pandemics. This involves establishing a typical pandemic reaction based on what mankind has seen in the COVID crisis. Furthermore, errors may be avoided by assessing the impact of the interconnected social bodies on the pandemic crisis, understanding the varied degrees of influence and recognizing how large the responsibilities each can play in suppressing the

pandemic outbreak. Furthermore, learning from the various countries' approaches [8] to coping with the pandemic in terms of unique measures adopted and lessons learned from each outbreak in the years 2019-2021 is critical. Different studies have reported different technologies to recognize and report the COVID-19 possibilities and some research studies have reported different technologies to prevent the pandemic in near future [6].

Figure 2. Covid-19 Emergency management Framework [7]

2.3 Research objective

Even after the global pandemic outbreak, there is an urgent need to effectively utilize existing technology to normalize the post-pandemic situation to avoid future outbreak. Internet of Things (IoT) technology is considered as one of the most significant techniques with a substantial promise in combating the future pandemic situations. Internet of Things is composed of a local network in which IoT devices detect their surroundings and provide important data to the Internet [9]. This research work explores the existing scenario of post-pandemic management related IoT applications, highlight implementation and operational issues, and provide potential solutions to further curb the outbreak. Furthermore, the factors and methodologies influencing the IoT implementation are also discussed.

3. Related Works

Since its onset in 2019, the COVID-19 pandemic has been one of the most researched topics. However, only few research articles have addressed the implications, development,

and difficulties of IoT in combating the post pandemic era [10]. Some of the similar publications are highlighted here.

In the post pandemic era, it is highly essential to early identify the COVID infected cases, Otoom et. al [11] have identified the COVID infection by obtaining the real-time symptoms from the intended person. Authors have used eight different machine learning algorithms and recorded the treatment response of each and every patient infected with the virus.

Priyanka et. al [12] have integrated wearable microsensors to monitor the post COVID patients from any remote location. Also, the authors have collected the data and successfully transmitted to the intended location.

Vedaei et. al [13] have designed and developed a IoT based autonomous surveillance model with a lightweight and economical IoT node, fog-driven machine learning tool and a smartphone application. The proposed model helps people to know about the real-time COVID-affected environmental risk. This will minimize the risk of COVID exposure in post pandemic life.

Poongodi et. al [14] have developed a robust IoT-driven healthcare systems to effectively administrate full COVID-19 management and analysis. The simulation results have validated the proposed model by identifying the violations in social distancing, predicting the COVID infected cases and disease spread probability.

In the post-pandemic life, most of the infected patients are advised to self-quarantine themselves in any remote location. Any violation on this preventive measure will lead to a significant threat to human community. Hence, Al Bassam et. al [15] have developed a wearable gadget to continuously monitor the health and recovery signs of the self-quarantine patients. The API of the wearable gadget gets continuously synchronized with a mobile application for alarming about any emergency situation. Recently, a wearable IOT design framework has been proposed to serve as an appropriate technical foundation for the proposed system implementations if implemented in its modified form [16].

As an advancement for IoT based Covid-19 management, N Naren et. al [17] a UAV and DNN integrated hybrid model for Covid-19 detection. The proposed framework also involves in incorporating an autonomous disinfectant system and secured user authentication models.

With the vast amount of Covid-19 related data being collected in the process of both surveillance and localized monitoring, Awotunde et. al [18] have developed a cloud integrated IoMT based model to track infected individuals' health conditions and store it in a distributed cloud platform by reducing the workloads of healthcare professionals.

Finally, Kwekha-Rashid et. al [19] have reviewed the influence of Artificial Intelligence techniques like Machine learning and reported how machine learning can be used to evaluate and prioritize COVID-19 occurrences in future healthcare programmes and plans.

Table 1. Internet of Things Technologies Implemented Towards Ensuring Quality Of Life in Post Pandemic Era

S. No	Author Details	IoT Technology Used	Outcome/Results	Advantages
1	Otoom et. al [11]	Wearable devices	Real-time data collected from users and sent to quarantine/isolation center.	The proposed method has achieved accuracies of more than 90 %.
2	Priyanka et. al [12]	Wearable IoT based micro sensors on human body and AI/ML architecture	Patient reports were instantly sent to obtain doctor verdict and report	Network security and big data analysis, the accuracy of the results has reached upto 93%
3	Vedaei et. al [13]	IoT device with LoRa, RPIZW, heartbeat & SpO_2 sensor, Temperature sensor and Bluetooth module	Successfully classified COVID and Non-COVID groups, and successfully simulated the real-time geolocation of COVID hotspots	Successfully communicated personal and regional data. The ability to process data locally allows the IoT node to be used in situations without internet access or fog-driven networks.
4	Poongodi et. al [14]	IoT and D2D communications, Graph-based	Identified dense populated function with COVID infection	This method successfully identifies the

		contact tracing model	and disease spread w.r.t time	possibly infected patients in two different cases: wearing masks or without mask.
5	Al Bassam et. al [15]	Wearable IoT sensor, cloud layer accompanied with Application Peripheral Interface (API) followed by an Android web layer	The API and mobile application synchronized and successfullypredicted and alarmed the COVID based situation	The proposed digital remote platform can be used to track the health and recovery of the COVID-19 infected patient.
6	Awotunde et. al [16]	IoT-based wearable body sensor	Successfully monitored early diagnosis, social distance, quarantine time period, and post disease recovery.	This model eliminates medical faults and reduces manual workload but tracking patients in both town and urban areas.
7	N Naren et. al [17]	Unmanned aerial vehicles, Internet of Things, deep neural networks (DNNs), and smart robots.	Successfully dispensing a COVID testing kit to user with UAV with a proper path planning technology	The proposed strategy is vital for eradicating COVID-19, particularly in rural locations with limited expert medical facilities.
8	Awotunde et. al [18]	Cloud-IoMT-based big data analytics	Successfully tracked patient health conditions globally	Reduces healthcare costs and enhances the medical diagnosis accuracy.
9	Kwekha-Rashid et. al [19]	Machine Learning [ML] technologies	Supervised learning has obtained better results than Unsupervised learning with 92.9% testing accuracy.	Discussed about the effectiveness of ML in prediction, investigation and discrimination process.

4. Open Challenges and Future Work

The following elements and technological modifications can be further explored to provide more advanced insights to the IoT driven smart cities in the post-pandemic era.

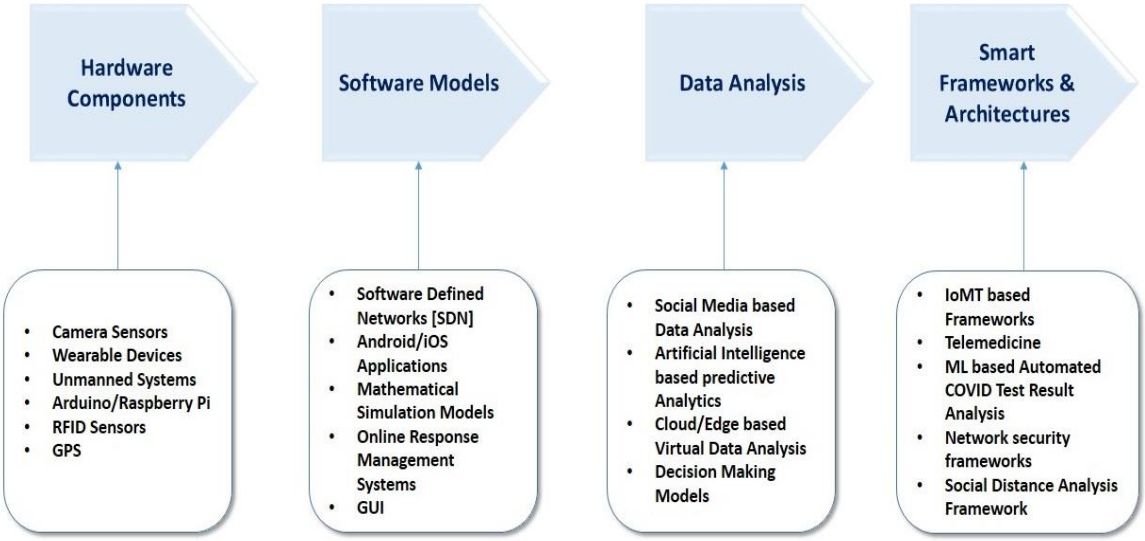

Figure 3. Future technology involvement in IoT

4.1 Hardware Models

Smart cities encompass a wide range of intelligent models to ease our everyday activities. In such instance, more novel research works can be proposed to introduce smart hardware models to obtain real-time values of pulse rate, oxygen saturation, and temperature even at the recovery stage. Developing new research directions on IoT frameworks [20] including camera sensors, wearable devices, unmanned systems (drones), Arduino/Raspberry Pi boards, and GPS devices will help in building a smart community to familiarize a technology driven lifestyle in the post-pandemic era.

4.2 Software Models

Networking, softwarization and automation are becoming the driving force for various emerging smart city applications. Developing a service-oriented software platforms for covid-19 analysis will play a significant role in combating the future pandemic situations. Novel software solutions [21] like software defined networks, mathematical and simulation models, cloud/edge/blockchain based resource management systems, and GUI interfaces can be implemented in various smart city applications like healthcare, industries, gaming, education etc. to: simulate the spread of any disease in any city or region using demographic

information from the geographic area that is being analyzed as well as disease-specific characteristics; develop autonomous models to interact with people in post-pandemic world; utilize software agents of social networks to analyse the disease spread groups; analyze the impact of pandemic restrictions; spread awareness about the related vaccination dose.

4.3 Data Analysis

The covid-19 pandemic outbreak not only revealed vulnerabilities and under preparedness in the conventional healthcare system, but it also provided an opportunity for telemedicine and data analytics to gain significant research attention. Data analysis has the potential to comprehend the impact of novel coronavirus, leveraging a source of information that can promote prevention and treatments in the future. Big data analysis [21] may also offer assistance in predicting the systemic changes in our society, economy, and way of life as a result of the pandemic. Although many big data technologies are proposed for performing COVID-19 warning and monitoring, the most urging challenges for big data technology during the post pandemic are preventing the disease's rapid spread and reducing its impact on society.

4.4 Smart Frameworks and Architectures

The pandemic's exact impact on smart cities is nearly impossible to determine. Nonetheless, technologists and researchers are eager to take this opportunity to rebuild stronger and renovate cities that are more sustainable, accessible, and resilient [22]. In the post-pandemic era, smart city should be rebuilt with smart frameworks and architectures like edge/cloud computing, artificial intelligence, machine learning, deep learning, sentiment analysis, chatbots and recommender systems to make the cities more efficient and responsive to the common population. Moreover, new frameworks should be proposed to ensure smart city initiatives comply with data protection and privacy protection and maintain a proper balance between individual privacy and public good.

5. Conclusion

In the past few years, pandemic has changes every aspect of human life. The recent surge in COVID-19 pandemic outbreak has necessitated the implementation of emergency services and when gradually the disease spread comes into control, the IoT based technologies are highly required to work efficiently and make a best utilization of pandemic resources to drive the post-pandemic situation in a reliable and accessible manner, This paper

has presented a comprehensive survey on the applications of wide range of IoT technologies in post-pandemic management. The paper first presented a detailed review on the integration of different IoT technologies in smart city applications. Then, it has been preceded by the discussion on the influence of COVID on the society and how the technologies has been effectively used in the crisis management during pandemic outbreak. The next phase reviews the consequences beyond covid-19 and post-pandemic care on the society and how the technologies influence in regularizing the post-pandemic situations and minimizing the future pandemic risk. Nevertheless, this research work has discussed about the different IoT based technologies that has been implemented to overcome the challenges in post-pandemic environment. Finally, the proposed study has sketched the various IoT technologies, existing changes and potential research directions.

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