Journal of Computing and Communication Vol.1 , No.2 , PP. 44-56 , 2022

Design and Development of smart kit for early-stage detection and prevention from covid 19 using IoT-connected devices

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ARTICLE DATA

Article history:
Received 03 June 2022
Revised 09 Aug 2022
Accepted 09 Aug 2022
Available online

Keywords:
Automation, Contactless Sanitization, Internet of things, Smart Healthcare, Smart Sensors

ABSTRACT

World Health Organization (WHO) recommends preventing infection by regular hand washing, wearing a mask in public places, covering the mouth and nose when coughing and sneezing, and avoiding close contact with anyone showing symptoms of respiratory illness. According to a study, people touch their faces more than 20 times an hour on average, which involves contact with the eyes, nose, or mouth. People often wear the same mask repeatedly without disinfecting them. Most of the population does not wear a mask or follow social distancing protocols, which leads to the further spread of the virus. This paper discusses a cost-effective and smart solution for citizens in the form of a smart kit that contains multiple Internet of Things (IoT)devices with shared connectivity, each addressing a particular problem, which makes following the pandemic protocols easier and effective, and safer for the average citizen and the frontline workers.

1. Introduction

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus. The virus that causes COVID-19 is mainly transmitted through droplets generated when an infected person coughs, sneezes, or exhales. These droplets are too heavy to hang in the air and quickly fall on floors or surfaces. But in certain cases, airborne transmission of the virus is also possible. Airborne transmission is different from droplet transmission as it is categorized by the presence of microbes within droplet nuclei, which are generally considered to be particles <5μm in diameter and can remain in the air for long periods and be transmitted to others over distances greater than 1 meter. You can be infected by breathing in the virus if you are close to someone who has COVID-19 or by touching a contaminated surface and then your eyes, nose, or mouth. The prevention of this virus requires simple measures, like following social distancing protocols, wearing a mask in public places, proper sanitization, and other personal safety measures [1]. But a majority of the population does not follow these measures properly. They are simple yet difficult for the average citizen to adhere to with seriousness. The Centre for Disease Control and Prevention (CDC) recently updated its guidance to state that face masks provide some personal protection against the virus for those who wear them, not just for those around them. New data from a randomized controlled study published in the Annals of Internal Medicine showed that wearing a mask was slightly more effective in preventing the virus than not wearing a mask in situations where other preventive measures like physical distancing are recommended [2]. The Council of Medical Research (ICMR) has issued a statement saying many irresponsible people not wearing masks and not maintaining social distancing are the major reason for the rise of the coronavirus pandemic. A survey spread over 18 cities initiated by ApnaMask, and an NGO has shown that only 44% of the people wear a face mask, although 90% have awareness. The data for social distancing and sanitization is even worse. The percentage of people in different sectors of the country following the pandemic safety measures is represented in Table 1[3].

Table 1
People following the pandemic protocols in different sectors of the country

Criteria	Rural Area	Urban Area	Public Places
Face Mask	24%	44%	30%
Social Distancing	28%	46%	12%
Sanitization	26%	50%	24%
Awareness	60%	90%	56%

Since the world is a major smartphone hub, connected technology is preferred even in many rural parts of the country. With the emergence of cheap internet facilities, many major applications such as education and jobs have taken the online route. Over recent years, smart devices with connected technology have had a predominant market in all sectors of the country [4]. This paper explains a smart kit that houses several smart devices interconnected with each other and to the user's smartphone, which provides efficient solutions for early detection and prevention of the virus. Since most of the population prefers smart technology, this kit makes following the pandemic protocols smarter, easier, hassle-free, and efficient. It is a cost-effective solution prevalent on the internet and a smartphone, which is already a basic household entity in the country. About 88% of households own a smartphone and almost more than half of them have access to the internet [5]

Internet of Things (IoT) is a rapidly growing technology that includes sensors and cloud computing. IoT has become one of the most significant technologies in this connected world, and in recent years, many electronic devices have started adopting the IoT standard. IoT applications have been developed and deployed in several domains such as transportation and logistics, healthcare, retail and supply chain, industry, and environment [6]. IoT in healthcare has been an emerging field in recent years and connected cities and devices have been very helpful in tracking and monitoring user data. The wider aspects include increased sanitation, which requires smart monitoring and control. In the case of health tracking, monitoring people for high temperatures or other potential indicators might be used as parameters for evaluation [7]. Smart technology can help manage people by gathering, crowd management, quarantining people, following the government guidelines properly, smart distribution of sanitization supplies and medicine, and implementing social distancing protocols [8]. IoT integrated with sensor networks, and robotics is highly effective in establishing a non-contact ecosystem and results in simpler monitoring and control systems. A few major applications of the architecture mentioned above include ensuring social distancing, providing smart and effective sanitization, implementing smart monitoring protocols, and faster evaluation of determination parameters [9]. With the emergence of smart Automation, IoT, and Artificial Intelligence of Things (IoT), devices and smart sensors, which come with nice comfort, ease of use, and painless detection of parameters, patients prefer using non-invasive sensor devices to help them manage their health. As a result, devices such as smart bracelets and smartphones are becoming increasingly popular in personal health care. The future of healthcare and sanitization and safety protocols have been rewritten with the emergence of the pandemic and the new normal has to emerge with smarter and affordable devices and solutions [7].

The rapid growth of data transmission and communication protocols with the increased demand for smart solutions have

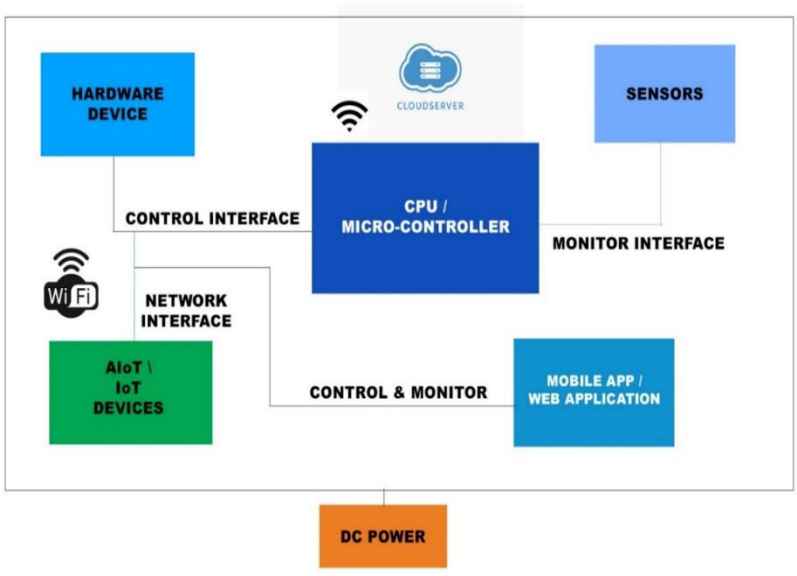

Figure 1: Proposed block diagram of IoT connected Covid Smart Devices

The integration of different sources of data can be one of the greatest transformations in our way of living in this century, along with the processing possibilities provided by data science, which can be used in efficient ways to handle the pandemic. This resulted in the growth of a connected world, which has been made the best use in the healthcare segment. The initial pandemic analysis demonstrated the virus's rapid spread and propagation when initial measures were not properly adopted and implemented. Such a lack of quick response is even more critical for highly populated areas, as seen in the pandemic's original epicenter [10].

The system proposed in this paper is a smart essentials kit, which can be used in various sectors, including domestic households, industries, institutions, offices, and other public places involving huge gatherings or crowds. Each product in the kit is designed to address a particular problem in a particular situation and uses smart connected technology and IoT standards to control, operate and manage different parameters. The block diagram representing the communication, hardware, and interfacing protocols is shown in Figure. 1.

This paper is organized as follows: Section 2 discusses the medical parameters for evaluating the virus in the patient. Section 3 deals with smart and effective sanitization methods to prevent the virus. The smart patient monitoring and tracking system are discussed in Section 4. Smart personal hygiene maintenance, screening, and prevention system are discussed in Section 5. The CPU, Hardware, and Software Interface details are illustrated in Section 6. The real-world analysis and comparison with traditional methods are discussed in Section, and appropriate conclusions from the study are discussed in Section 7.

2. General Medical Parameters for Evaluation

2.1. Temperature

The proposed system is a smart essentials kit, which houses several smart devices that help tackle the Covid situation smartly and effectively. For a smart healthcare device, monitoring the parameters of a patient is an important criterion. There are many ways to measure the temperature of objects. The temperature measurement can be mainly divided into contact measurement and non-contact measurement. The temperature sensor is interfaced with a Nodemcu ESP8266 module, via which temperature is continuously monitored and stored on a web server. The patient's temperature is continuously monitored, and the data is stored in a cloud server, which can be accessed in real-time via a mobile application. To monitor the patient's temperature, standard temperature sensors are used. The temperature can be calibrated, stored, monitored, and accessed based on the user's convenience.

2.1.1 Contact Measurement

LM35 is a temperature sensor that outputs an Analog signal proportional to the instantaneous temperature. The output voltage can easily be interpreted to obtain a temperature reading in Celsius. The advantage of lm35 over thermistor is it does not require any external calibration. The coating also protects it from self-heating [11]. The system is a continuous monitoring setup plugged into the user.

2.1.2 Non-Contact Measurement

MLX90614 is an optical infra-red temperature sensor[12]. It has Infra-Red radiation receptive thermopile and Acoustics Speech and Signal Processing (ASSP) on the same TO-39 cascading. This temperature measuring device is surfaced with the digital Pulse width Modulation and System Managing Bus. The user's temperature can be measured from a distance of 2 feet. This eliminates the need for unnecessary contact. The mentioned system is a continuous setup, which can be accessed according to the user's convenience.

2.2 Heart rate

Pulse measurement is an important criterion in health monitoring. A standard pulse sensor SEN-11574 is used to monitor the patient's vitals. The sensor measures the pulse using an optical measurement system in the form of vibrations. This provides accurate results and provides a better health tracking system.

2.3 Oxygen saturation

Oxygen saturation levels play an important role in determining the presence of the virus. A standard oximeter sensor, MAX30102 is used to measure the oxygen level. It uses a light absorption technique to measure oxygen levels. Light beams pass through the blood to determine the amount of oxygen in the blood.

3. Smart and Effective Sanitization Methods

Since Covid is a contagious disease, proper monitoring, screening, and, most importantly, effective sanitization is required. The current technology predominantly uses liquid sanitization, and in rare cases, gaseous sanitization is involved. There exists another smart sanitization method which is UV light sanitization. This is a non-contact method, and the results are comparable with the traditional sanitization methods.UVC radiation is a subtype of radiation that is used for killing bacteria and viruses. It

has a high intensity and kills viruses and bacteria due to the shorter wavelengths. UVC radiation cannot reach the earth's atmosphere due to the ozone layer.

This radiation technology is beneficial for reducing the effect of the virus by integrating it with smart control measures. Another source of domestic sanitization has become essential in places where large gatherings of people can be seen. The traditional sanitizer dispensing mechanisms are tedious and, in most cases, self-contaminated. To avoid such circumstances, a smart non-contact dispensing mechanism has been employed for clean, hassle-free sanitizer dispensing with the facilities to monitor and clean the mechanical parts. In addition to sanitizer dispensing, a vending machine has been made to provide clean masks to the public. All the mentioned systems can be used independently or as a connected system depending upon the place of use.

3.1 Portable Covid Clinic (Smart UV Disinfection Box, Smart Sanitizer, and Mask Dispenser)

In this proposed system, the first product in the smart sanitization kit is a smart Portable Covid Clinic which houses a UV Disinfection Box, Smart Sanitizer, and Mask Dispenser. The UV disinfection box has a non-contact opening mechanism powered using an SG-100 servo motor equipped with robotic arms. It is designed with an inbuilt 360o cleaning system. Masks can be reused after sanitization using the smart UV disinfection box. The box is also capable of sanitizing other medical or domestic equipment. The block diagram for the smart UV sanitization box is shown in Figure2.

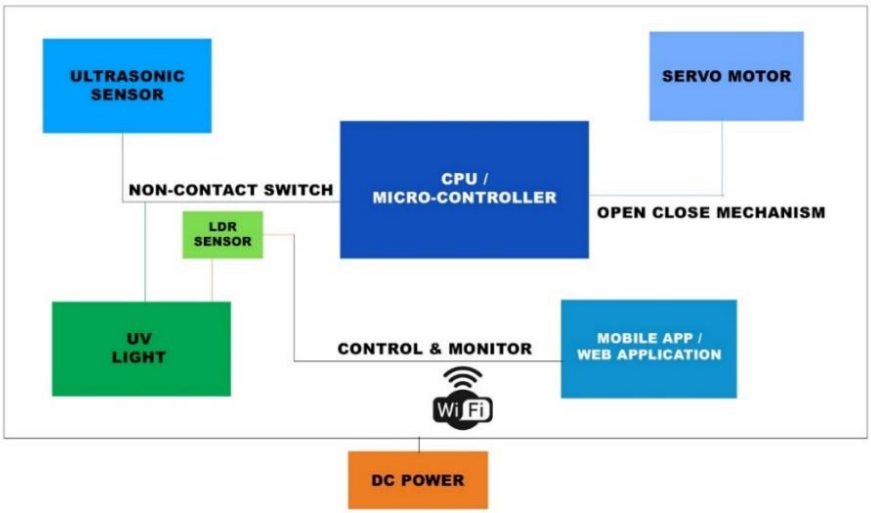

Figure 2. Smart UV Box Block Diagram

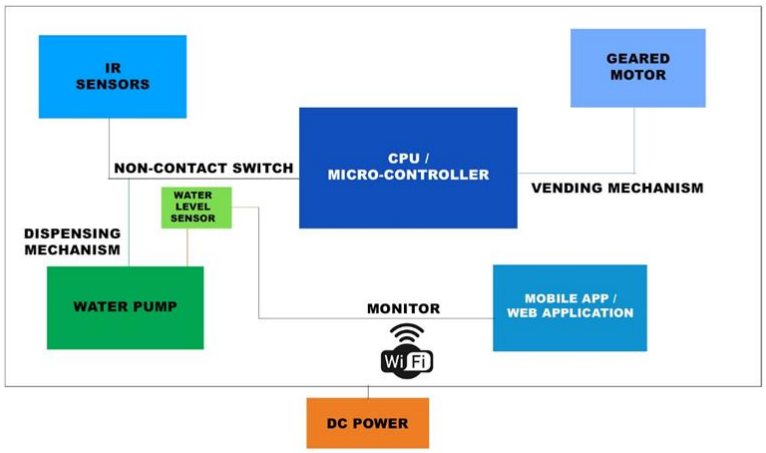

Figure 3. Smart Sanitizer and Mask Dispenser Block

The system can monitor the light intensity using the GYML8511-UV Light sensor, and the intensity of the light can be adjusted based on the product to be sanitized. An inbuilt 555 timer ensures that the contents are properly sanitized. The box opens and closes automatically or can be opened or closed manually via an ultrasonic sensor HC-005 which acts as a non-contact switch in the manual mode. The TUV11W-UV light is activated only when the box is closed, ensuring the user's safety, preventing them from looking directly at the light source, and avoiding any other source of harmful contact. The box can be operated in two

modes, manual mode and an automatic mode, based on the place of use. The mechanism is connected via a mobile app or a web application, and the different aspects of the system can be controlled and monitored remotely via a local network. The operating standards and the communication protocols are designed to follow the latest industry 4.0 standards. The internal mechanism of the UV Sanitization box is shown in Figure 4.

Figure4. Hardware prototype of UV disinfection box

The next attached setup is a Smart Sanitizer and Mask Dispenser. EC-0141 IR sensors are used as a non-contact switch for triggering the sanitizer and mask dispensing mechanisms. The IR sensor is calibrated so that when the user places their hand at a particular distance in front of the sensor, the switch is triggered for the respective mechanisms. A DC6-12V submersible water pump is used to dispense the liquid sanitizer. An SPG30E-30K geared motor is used to operate the vending machine to dispense the masks. The block diagram for the Smart Sanitizer and Mask Dispenser is shown in Figure 3.

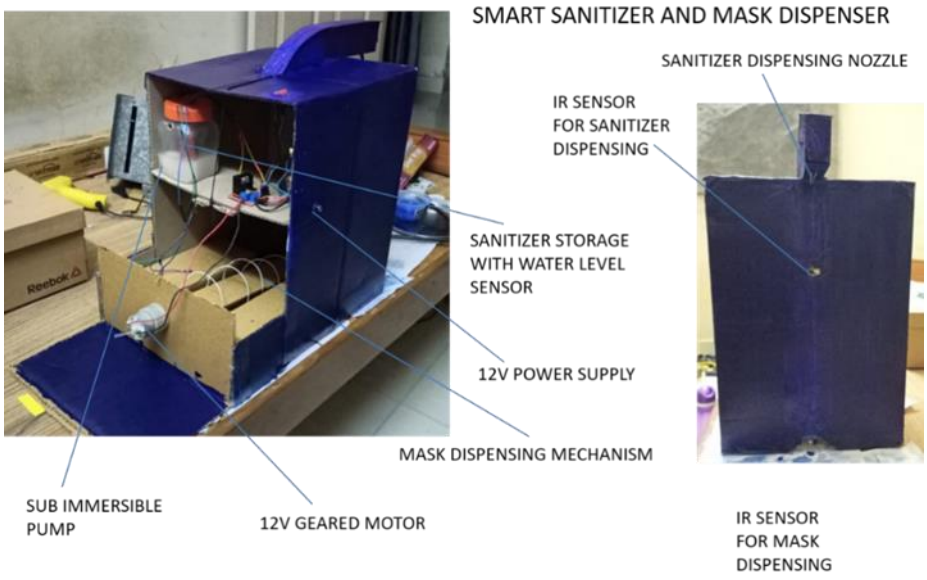

Figure 5. Hardware prototype of Smart sanitizer and Mask dispenser mechanism

The system is designed with the vision for a post-covid smart dysfunction solution in public places, where frequent sanitization is needed. The sanitizer container is equipped with a DC3-5V water level sensor, via which the user can monitor the level of sanitizer in through a mobile app or a web server. The Mask dispensing unit can also be altered to house medicines and other medical units required by the general public [13]. The hardware prototype of the smart sanitizer and mask dispenser is shown in Figure 5.

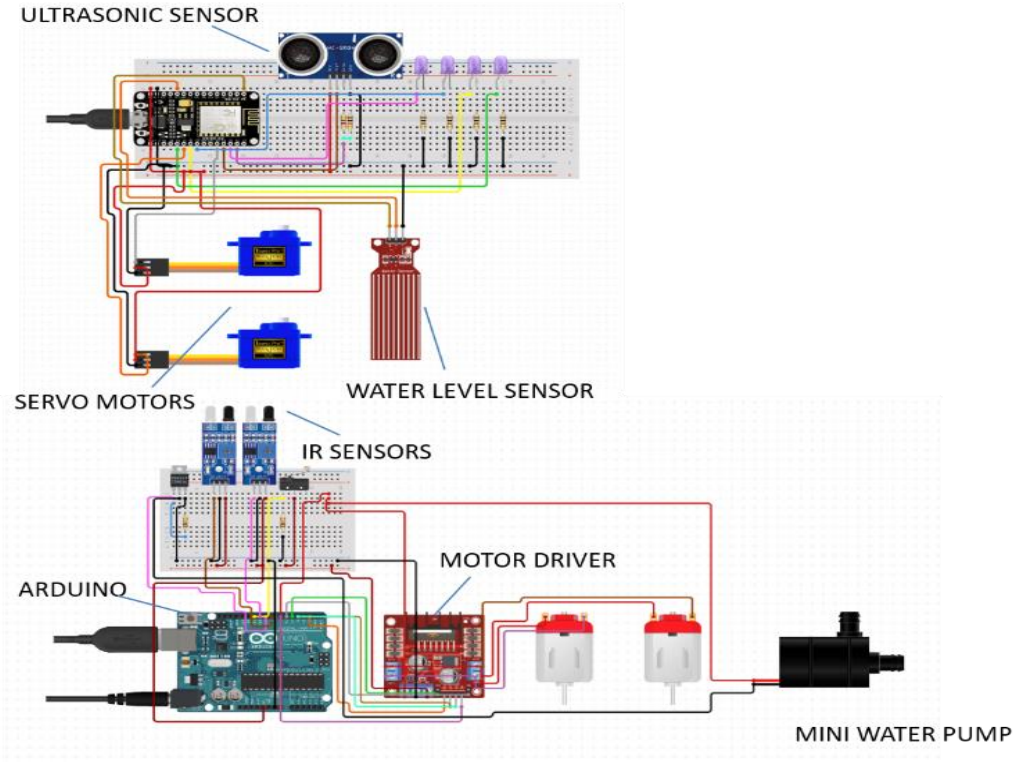

Figure 6. Smart Portable Covid ClinicCircuit Configuration

Figure 7. Hardware prototype of Smart portable covid clinic equipped with contactless sanitizer, mask and UV disinfection box

3.2 Smart Disinfectant Rover

A movable rover bot is equipped with TUV11W-UV light to sanitize areas where human interference is not possible or unsafe. The UV light is placed at an angle where maximum sanitization efficiency is achieved. The rover is built with a strong shock absorbent multi-frame chassis with four-wheel drive via enhanced SPG30E-30K geared motors. The rover can sanitize rough

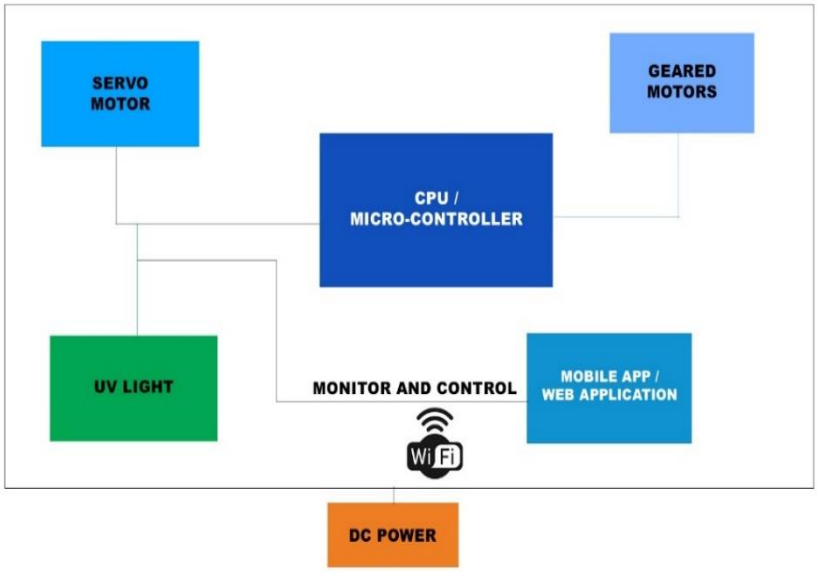

Figure 8. Smart Disinfectant Rover Block Diagram

areas and climb onto high altitudes, with the help of the high-duty precision geared and servo motors combination. The bot is controlled using a mobile app or a web application via a local network. The block diagram for the proposed system is shown in Figure 8.

The ultra-durable chassis ensures effective sanitization and a quick and efficient process due to the high-intensity UV light placed under the rover. The control and transmission are designed based on the latest Industry 4.0 protocols, and the transmission is smooth, fast, and lag-free due to the advanced connectivity protocols.

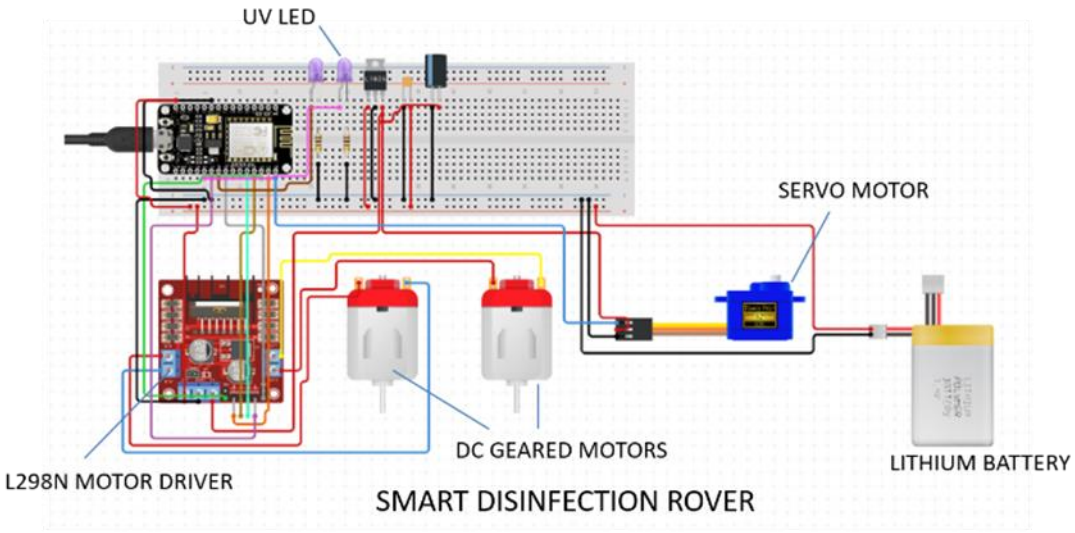

Figure 9. Smart disinfectant rover circuit configuration

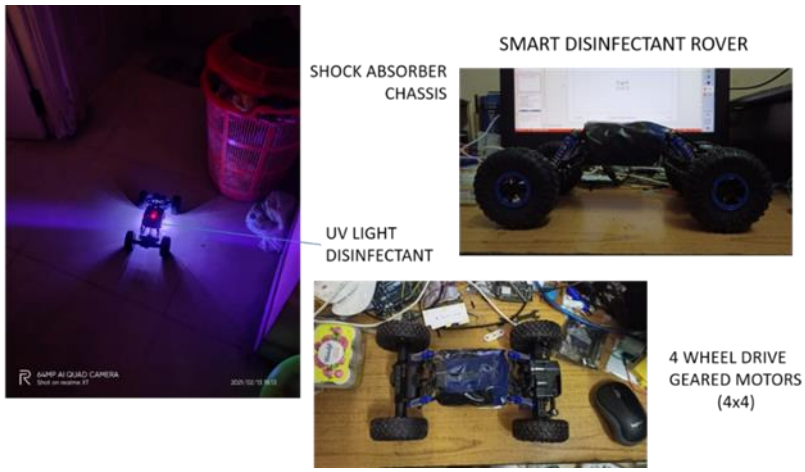

Figure 10. Hardware Prototype of Smart disinfectant rover

4. Smart Patient Monitoring and Tracking

GPS technology is one of the most sought-after technologies to track, analyze and monitor an individual or a group. During times of crisis like the Covid pandemic, GPS technology has played a valuable role in ensuring all safety protocols [14]. The next product in the smart essentials kit is a smart patient monitoring and tracking system that can be employed on an individual or a group to monitor, administrate, ensure safety, and prevent protocol breaches. The proposed is in the form of a band housing a temperature sensor and a NEO-6M GPS module. The user's temperature is monitored continuously using an LM-35 temperature sensor, and the data is stored on a server. The data can be monitored via a mobile app or a web application.

Real-time data is processed, and the readings are used as an evaluation parameter to screen patients [10]. The inbuilt GPS module ensures the patient's location and maintains proper quarantine protocols. The user's location data is continuously monitored, and a quarantine perimeter is enabled. When the perimeter is breached, an alert is sent to a mobile app, and thus hospitals and other places are isolated; quarantine or tracking is required to ensure proper protocols. The block diagram for the proposed system is shown in Figure 11. The patient monitoring interface can be connected to a common server or database where several recipients can be monitored simultaneously. The smart band is designed with lightweight plastic material to ensure proper comfort for the user for 24 hours of continuous use. The device can also perform enhancements like heart rate and blood oxygen level measurements. Based on the preference of the user, the add-ons can be modified. The data can be fed to neural networks or advanced Machine learning algorithms for smart screening. The system can also be linked

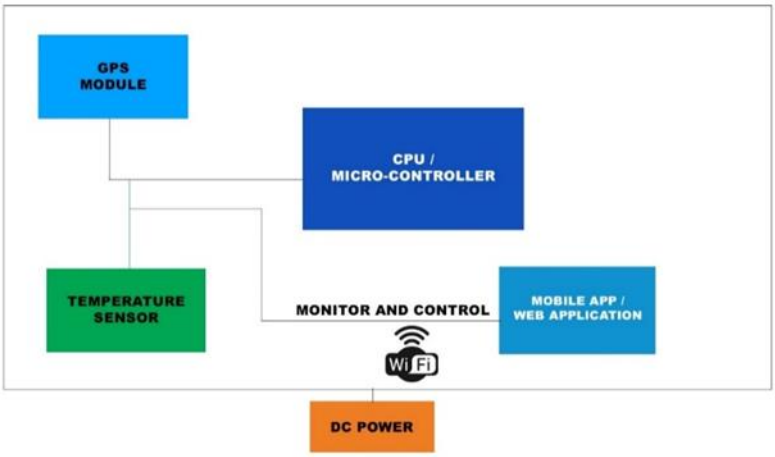

Figure 11.Smart Patient monitoring and tracking system block diagram

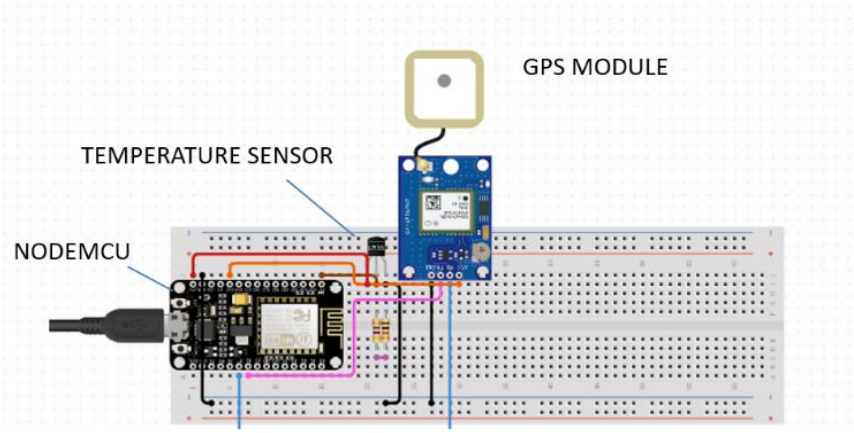

Figure 12. Covid Patient Monitoring System Circuit Configuration

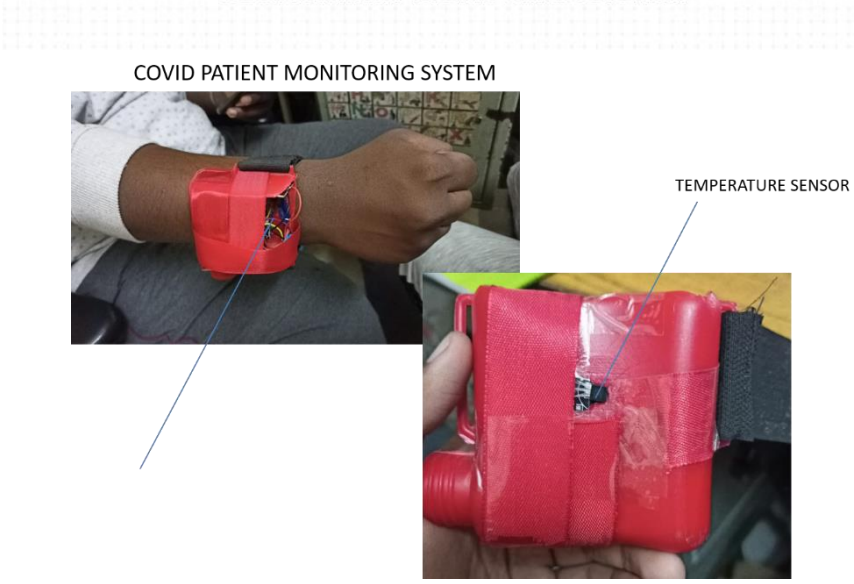

Figure 13. Hardware prototype of Smart Patient Monitoring and Tracking system

With other patient vitals and personalized health, the report can be generated, and the datasets can be manipulated using smart algorithms. They can be used as reference data for IoT devices.

5. Smart Personal Hygiene, Screening, and Prevention

Personal hygiene has been an important factor in the spread of the virus; lack of personal hygiene, poor screening, and not following safety protocols has led to the tremendous rise of the virus. The common people do not happily welcome traditional safety techniques [15]. On the other hand, healthcare workers face difficulties with the existing solutions. The next product in the smart kit is an affordable solution for the common public and healthcare workers. The proposed system is based on non-contact techniques for daily scenarios. The products use a simple and affordable electronic smart mechanism to provide a smarter, easier, and hassle-free solution to follow protocols and make personal hygiene and social distancing more effective.

5.1 Smart Mask and Face Shield

It is a lightweight, non-contact smart mask with a face shield, which can be operated via gestures, a mobile app, or a web application. The device is equipped with two high-precision lightweight servo motors, which serve as the mask and face shield's opening and closing mechanisms. A smarter mechanical arm mechanism has been designed to limit the number of components and the overall weight and to ensure hassle-free operation. Two EC-0141 IR sensors are placed on each side and act as non-contact switches. The top part of the device has an LM-35 temperature sensor that monitors the user's temperature continuously. The mask and shield are connected to an SG-100 servo motor via a lever mechanism. The masks and shields are replaceable after use. The device is mainly aimed at healthcare workers and can also benefit the common people. The block diagram for the proposed system is shown in Figure 14. The device has two-way communication protocols and can be controlled via Software and onboard hardware. A smart battery management system has been implemented to distribute adequate power among the micro components.

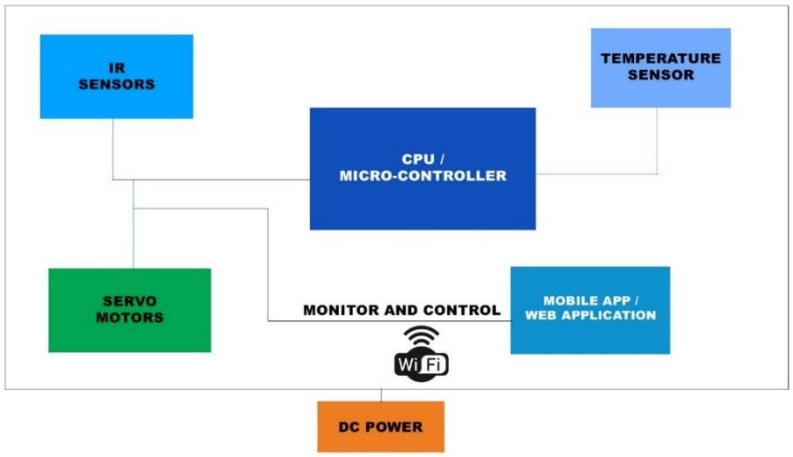

Figure 14. Smart Mask and face shield block diagram

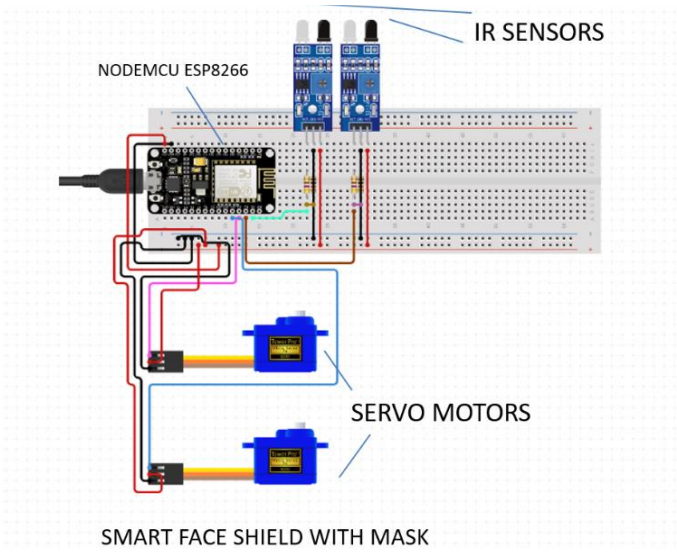

Figure 15. Smart mask and face shield circuit configuration

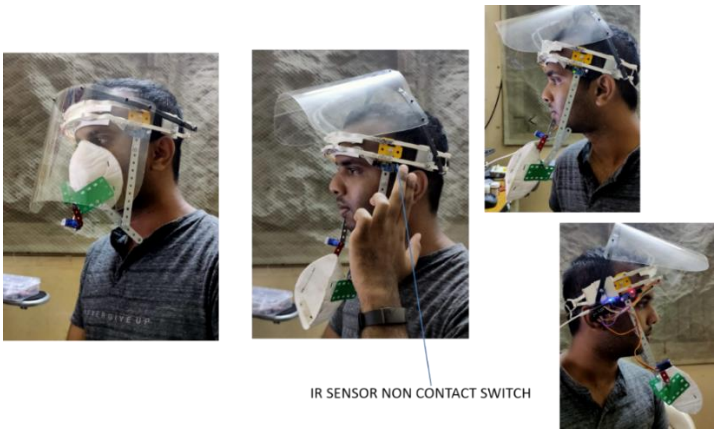

Figure 16. Hardware Prototype of Smart Mask and face shield

5.2 Smart Doorbell / Screening system

It is a smart anti-touch doorbell with an inbuilt optical non-contact temperature sensor. The doorbell is triggered via an HC-005 ultrasonic sensor as the switch. The bell circuit is activated when the user places their hand in front of the ultrasonic sensor, and the MLX-90614 optical temperature sensor is ready to measure the visitor's temperature [16]. The temperature data is transmitted to the inmate's mobile phone, and the person can be screened based on their temperature.

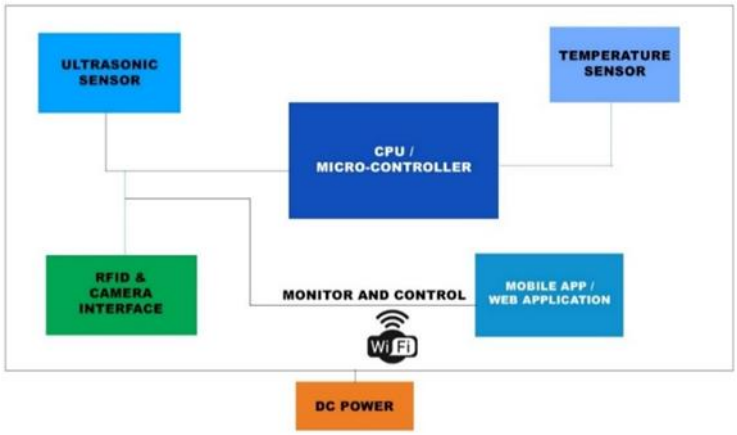

Figure.17 Smart Doorbell / Screening system Block Diagram

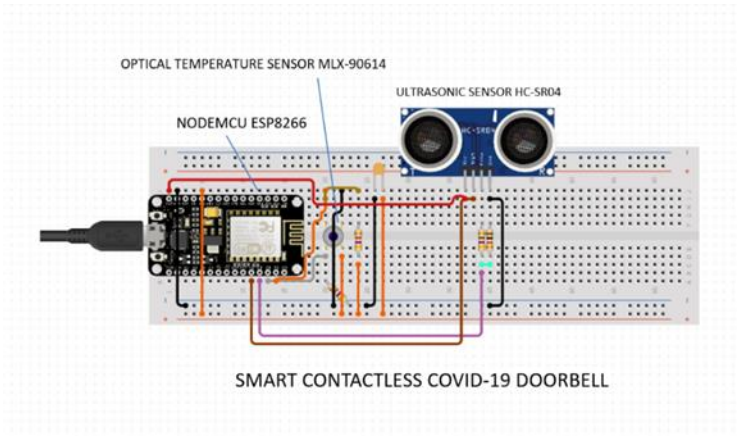

Figure 18. Smart Contactless COVID 19 Doorbell Circuit Configuration

This system is mainly designed for domestic households to operate as a doorbell. The block diagram of the proposed system is shown in Fig. 17. All the temperature data are stored in cloud servers and the device can also be interfaced with a camera or an RFID (Radio Frequency Identification) sensor to be used in mask detection and student or employee screening respectively in the places of requirement. The other use cases are in public places such as schools, colleges, and movie theatres. This ensures early screening of patients and faster prevention of the virus.

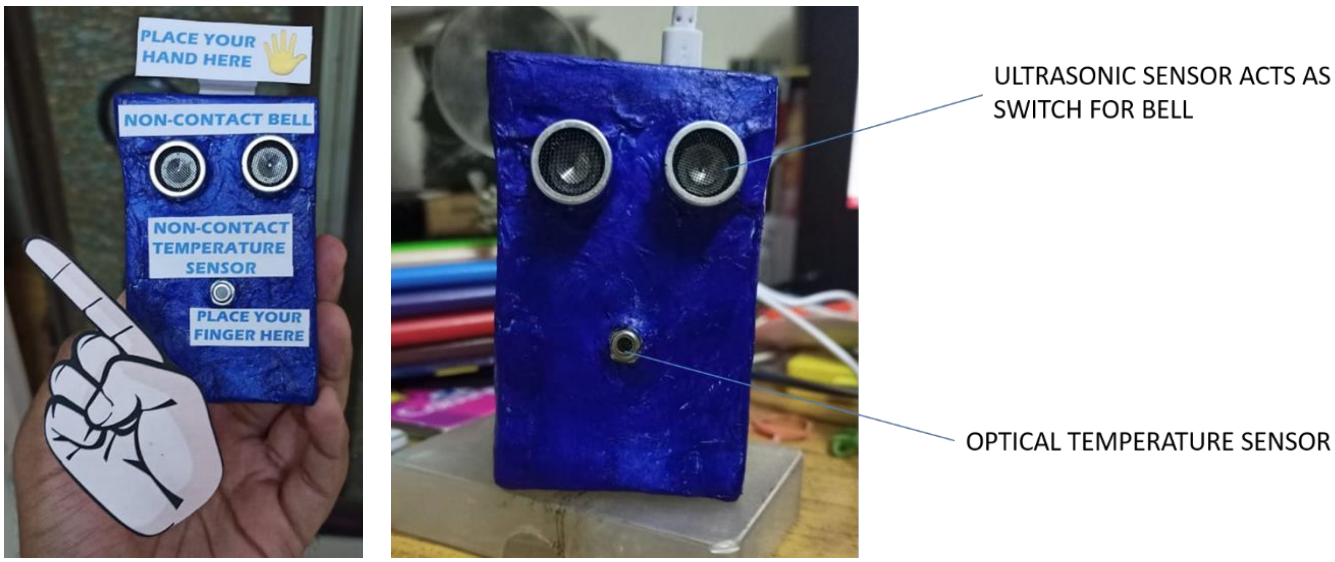

Figure 19. Hardware prototype of Smart doorbell / Screening system

6. CPU, Hardware, and Software Interfaces

Nodemcu ESP8266 is the primary hardware of the system, with the ESP architecture serving as the system's brain. The entire system is based on the ESP8266 architecture for integration with the various sensors and data transfer via a local area network. The Software is based on static and dynamic web pages and mobile applications. Other supporting hardware like Arduino and motor shields have interfaced with additional sensor operation and control.

Portable and efficient power supplies and lithium polymer batteries have been employed to power most of the hardware. Standard sensors have been interfaced via Software and calibrated to provide accuracy and precision over the monitor and control operations [10]. The hardware and the software architecture are shown in Figure 20. The software set is represented in Figure 21. The devices are designed to be part of a unified control system based on the main configurations. Blynk IoT architecture has been used for the mobile app interface.

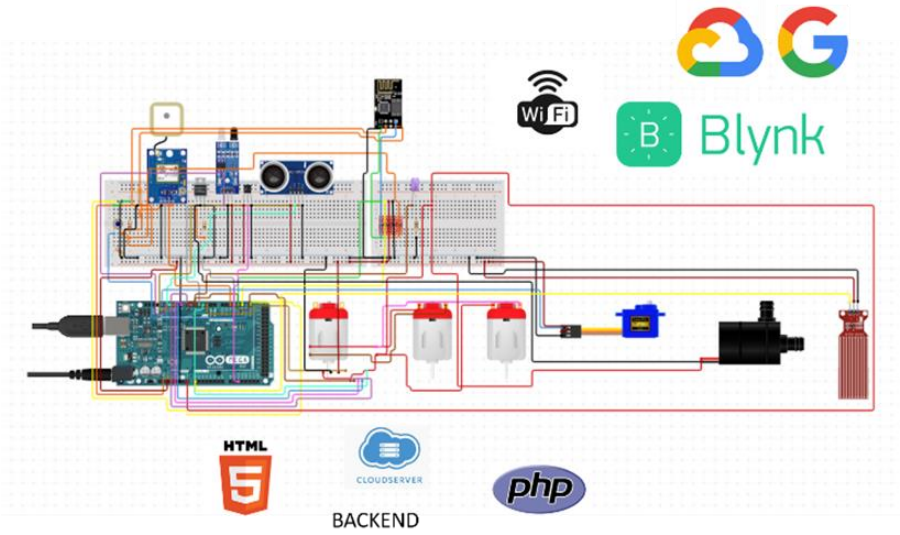

Figure 20. Software Interface with Hardware

The IoT and AIoT standards have been followed in the interconnection of all the systems. The proposed system is also compatible with the emerging IoT 5G standards in the faster data transmission, control, and monitoring over various fields, with healthcare being the main focus. Html, PHP, and Google web services have been used in processing data.

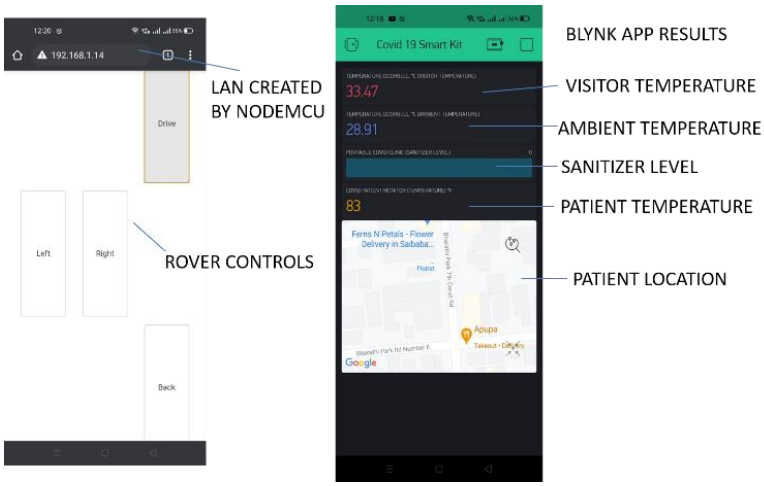

Figure 21. Hardware and Software architecture

7. Proposed System Comparison with Existing System

Based on the analysis in the practical world and the comparison with traditional methods, the smart alternatives have increased efficiency based on the results. The outcomes have been tabulated as follows:

Table 2
Comparison between existing and proposed systems

Ref.	Existing Smart System	Proposed Smart System	Efficient Outcome of Proposed System
[10]	Mask and face shield with manual operation, integrated with voice speakers	Non-contact mask and face shield	The smart alternative is much cleaner, hygienic, and hassle-free
[13]	Manual Sanitizer dispenser	Contactless sanitizer dispenser	Hygienic, safe, and easy to use
[14]	Individual manual patient monitoring with temperature and oxygen monitoring	Smart patient monitoring system	Convenient, risk-free, and can monitor many patients at once
[15]	One-time use masks, 7-day use clinical masks	UV box allows mark reuse	Cost-effective disinfection of deadly viruses enables reuse
[16]	Manual Liquid based cleaning, robot-based liquid sanitization	Rover with UV-based cleaning	Hassle-free, non-contact, and efficient cleaning
[17]	Switch-based doorbell with camera monitoring	Non-contact doorbell with temperature monitor	Helps maintain hygiene and provides early screening and prevention

7. Conclusion

Until a proper vaccine is introduced, Covid-19 prevention and the implementation of safety protocols is a tedious process with the existing manual technology and the mindset of today's digital and connected generation. Smart alternatives are the need

of the hour. With the rapid growth of the internet and the different generations of bandwidth, smart devices with connected technology with the latest IoT standards are the perfect solutions to tackle a pandemic of this scale. With the help of connected technology, there are a lot of opportunities to make the lives of healthcare workers and the general public easier, simpler, and hassle-free. With big cities under lockdown and most public places remaining closed, the new normal is difficult to adhere to; hence, a smart alternative would be the apt solution to bring back the normal scenario with a safer environment. Smart technology, smart healthcare, and smart delivery systems are the future for implementing smart cities to reduce the COVID-19 risk. It has been observed that these technologies are very useful for maintaining the different protocols such as social distancing and isolation and tackling the lockdown situation, reducing the spread of the virus.

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