A Modified Portable Health Clinic System for Coronavirus Hotspot Areas

Mustafa Qassab[1] and Qutaiba Ali[1]

[1]University of Mosul

April 12, 2022

Abstract

This study applied the World Health Organization (WHO) guidelines to redesign the Portable Health Clinic (PHC), as a Remote Healthcare System (RHS), for the spread of COVID-19 containment. Additionally, the proposed system not only collects people data but also classifies the case according to the the main symptoms of coronavirus using the COVID-19 triage process (CT-process) based on the analysis of measurement readings taken from patients, where drones are used as a PHC platform and are equipped with the required sensors and essential COVID-19 medications for testing and treating people at their doorstep autonomously when a full curfew is imposed.

A Modified Portable Health Clinic System for Coronavirus Hotspot Areas

Mustafa Siham Qassab, Qutaiba Ibrahim Ali

Computer Engineering Department, University of Mosul, Mosul – Iraq

Abstract

This study applied the World Health Organization (WHO) guidelines to redesign the Portable Health Clinic (PHC), as a Remote Healthcare System (RHS), for the spread of COVID-19 containment. Additionally, the proposed system not only collects people data but also classifies the case according to the the main symptoms of coronavirus using the COVID-19 triage process (CT-process) based on the analysis of measurement readings taken from patients, where drones are used as a PHC platform and are equipped with the required sensors and essential COVID-19 medications for testing and treating people at their doorstep autonomously when a full curfew is imposed.

Keywords: COVID-19, drones, remote healthcare system, portable health clinic, full curfew.

Introduction

Coronavirus disease, or COVID-19, is an infectious illness that has been discovered recently [1]. This virus was unknown before the Wuhan chain occurrence in December 2019, and by April 2022 over 490 million people globally are infected and over 6 million have died [2]. COVID-19's most like to appear symptoms are fever, fatigue, and dry cough. Furthermore, several patients also experienced runny noses, nasal clog, sore throat, throbbing pain, or diarrhea [3]. Individuals get infected by this virus through tiny beads when coughing, sniffling, or talking during close contact [4], these beads fall to a surface or ground making contaminations over long distances [5] with a survival time of up to 72 hours [4]. On 11 March 2020, the WHO announced it was a pandemic. At that point, numerous countries have imposed nationwide lockdown, especially in COVID-19 hotspots with an aggressive promotion of the social distancing concept in the media to raise awareness. A hotspot is a district where reports indicate a relatively larger number of confirmed COVID-19 infections [6]. This motivates the idea of this paper, where populations under a curfew are being tested for COVID-19 symptoms at their doorsteps with minimal human intervention by using a portable health platform comprised of Unmanned Aerial Vehicles (UAVs).

The uniqueness of the proposed approach is that the PHC platform is fully automated and delivers the COVID-19 testing and medication services to one's doorstep during a full curfew. The rest of the paper is organized as follows; Section 2 presents related work, while section 3 compares traditional and drone-based COVID-19 data collection, and the design methodology is explained in section 4. The redesigned PHC system is discussed in section 5, then the discussion and comparison with other works are mentioned in section 6. Finally, conclusions are brought in section 7.

Related Work

After the development of Information and Communication Technology (ICT), Internet of Things (IoT)-based systems received great acknowledgment from healthcare application developers [7] as a highly feasible alternative for COVID-19 control. IoT technologies offer a variety of services in such a contagious environment, e.g. telemedicine services, diagnosing coronavirus patients, tracking the coronavirus contamination pattern, and combining these services with wearable devices [8].

Drones, as carrying platforms of IoT payload can be utilized [9, 10] and most developed countries support the drone-based approach because it offers a safe way to help humanity [11]. Tracking the time scale of COVID-19 events with research efforts; one of the earliest applications studied and adopted to combat the COVID-19 pandemic was the delivery of life-saving medicine [12], followed by research on public monitoring [9] and data gathering [13] respectively. Thereafter, spreading disinfection on hot-spot surfaces was suggested by research. Finally, offering communication coverage was also an area for investigation by researchers.

For delivery missions, in [14] drones capability of drones for distributing viral tests to possibly infected patients using existing drone infrastructure is investigated. Furthermore, an automated drone-based food and parcels delivery for residents during curfews is considered in [12]. Delivering life-saving medicines in faraway hospitals using drones is investigated in [15]. Also, an automatic COVID-19 emergency response system to deliver supplies at low transportation cost based on a combination of blockchain and a multi-UAV network is proposed in [16].

For surveillance and public statements, in [17] drones fly over a congested area for social distance monitoring. Additionally, in [18] UAVs with equipped surveillance cameras and loudspeakers are used to inform people about the guidelines in case of emergency. Moreover in India, a drone-based system is used for monitoring social distancing and telling individuals the right way to wear a mask [11], similar to [9], where a preprogrammed flight route UAV is utilized for mass monitoring and quarantine zones reinforcement, and the operator is notified if social distancing regulations are not followed.

UAVs can participate in data gathering during COVID-19, wherein [13] an Arduino-based drone with mounted optical and thermal cameras is built to collect people's temperature and face information and transmit live video to a smartphone located inside Virtual Reality (VR) glasses worn by the pilot. Another study investigates what so-called pandemic drones, which are remotely steered aircraft systems created by a Canadian aircraft manufacturing company named Draganfly, are used to improve emergency response time, health status monitoring, and infectious and respiratory issues detection [19]. Also, in [11] drone's real-time data gathering process from wearable sensors, movement sensors, cameras, and thermal scanners is discussed, where UAV is considered as an edge intelligence to process data and avoid collisions.

Showering of disinfectants is another area where UAVs can participate similar to sprinkling pesticides in agriculture [18]. In [19], South Delhi Municipal Corporation (SMDC) in India deployed drones to sanitize COVID-19 hotspots by spraying a disinfectant containing 1% sodium hypochlorite solution. Also, a simulation study in [6] considers statistics about drones for outdoor sanitization with variations in the number of drones, periods, and the percentage of individual drone utilization. While in [20] a real drone is used with a disinfecting tank for sanitizing indoor and outdoor environments as needed.

Drones can be used for providing communication coverage, as in [21] UAVs are used to offer reliable communication links establishment and maintenance between certain ground vehicles. Similarly in [17], UAVs are utilized as message relays in the vehicle-to-vehicle communication architecture during COVID-19 lockdown so the health status of passengers can be delivered steadily to the health workforce, and in the event of an accident, drones arrive nearby and gather information from close vehicles. Furthermore, a hybrid vehicle delivery system is proposed in [18] that uses both ground vehicles and UAVs for delivery during the COVID-19 pandemic, and the vehicles collaborate by organizing and maintaining stable communication links.

Additionally, a mixture of services can be provided by drones during the COVID-19 outbreak, as in [22] where UAVs offer multiple services like testing, contact tracing, sanitization, protocol enforcements, and spread analysis. Also in [11], a UAV-based healthcare system architecture that suits several COVID-19 handling situations is proposed and is applied in both real-time and simulation-based scenarios providing surveillance, announcement, live video communication, sanitization, thermal image capturing, and patient identification (ID) for large areas.

All the COVID-19 combating drone-based system applications and case studies reviewed in this paper and several other similar papers highlight the fact that the possibility of using UAVs in the healthcare sector could reduce response time effectively and overcome natural restrictions. However, the problem statement, medical professionals, patients, database, way of communication, and drone manufacturers should be considered in designing such systems.

COVID-19 Data Collection: Traditional vs. Drone-based Methods

Approach Type / Factor	Traditional Approach	Drone-based Approach
Health workers are needed in field	Yes	No
There is a direct-human contact when collecting data	Yes	No
Personal Protective Equipment (PPE) is needed	Yes	No
A mean for transportation is needed for health workers	Yes	No
Hygienic measures of staff are needed after completing the tour	Yes	No
Disinfecting the tools used in the tour	Yes	Yes
Parallel data collection possibility	No	Yes
Reduces the workload and stress on frontline healthcare workers	No	Yes
Reaching hard-to-access areas easily	No	Yes

In [14], the authors mention a traditional COVID-19 data collection approach named Vehicle-Based Testing (VBT) used by the state Red Cross Organization, this approach could be briefly compared to our suggested drone-based approach in Table 1.

Table 1: Traditional vs drone-based COVID-19 data collection approaches.

Design Methodology

WHO guidelines for combating COVID-19 are followed in this study as a theoretical basis of the designed PHC system to meet the general requirements in the service, which include [23-25]:

- **Primary screening and triage:** Screening and isolation of all suspected COVID-19 once in contact with the healthcare system to allow for proper prevention and control actions.
- **Prevention and control:** Isolation prevents viral transmission and quarantine may be at home or hospital depending on the patient's health status.
- **Traceability and privacy:** Infection could be direct or indirect, so contact tracing is essential to identify people who may have had exposure to a confirmed COVID-19 patient and trace all possible contacts with keeping the patient's privacy.
- **The Proposed Platform Specifications**

Many researchers have adopted a commercial multi-rotor UAV as a platform, which is the DJI

Phantom Pro v2, for different applications [26-29] and hence it has been selected in this research. A network of autonomous commercially available DJI Phantom Pro v2 quadcopter drones creates a swarm consisting of one Leader Drone (LD) and many Slave Drones (SDs), specifications are illustrated in Table 2 [30]. It is also assumed that each drone has two IoT Wi-Fi modules to control the drone flight and enable network capability as in [31]. SDs can communicate with the LD as well as transmit, receive and react to flight control codes to implement any required flight plan. Additionally, the Fifth Generation of cellular networks (5G) is used by the LD as in [8] for long communications i.e. with the base station. Therefore, the LD needs to be more powerful and durable than other SDs so it is assumed to have a double battery capacity, which can be done by soldering another battery in parallel to the existing one.

Aircraft and Camera	Weight: 1375 g, Diagonal Size (Propellers Excluded): 350 mm, Max Ascent Speed: S-mode: 6 m/s, P-mode: 5 m/s, Max Descent Speed: S-mode: 4 m/s, P-mode: 3 m/s, Max Speed: S-mode: 45 mph (72 kph), A-mode: 36 mph (58 kph), P-mode: 31 mph (50 kph), Max Wind Speed Resistance: 10 m/s, Max Flight Time: Approx. 30 minutes, Satellite Positioning Systems: GPS/GLONASS, Hover Accuracy Range (with GPS Positioning): Vertical: ±0.5 m, Horizontal: ±1.5 m, Camera Sensor: 1-inch CMOS, Effective pixels: 20M, Max Video Bitrate: 100Mbps, Supported SD Card: microSD, Capacity: 128GB.
Infrared Sensing System	Obstacle Sensory Range: 0.6-23 feet (0.2-7 m), FOV: 70° (Horizontal), ±10° (Vertical), Measuring Frequency: 10Hz, Operating Environment: Surface with diffuse reflection material, and reflectivity >8 percent (like wall, trees, humans, etc.)
Intelligent Flight Battery	Capacity: 5870 mAh, Voltage: 15.2 V, Battery Type: LiPo 4S, Energy: 89.2 Wh, Net Weight: 468 g, Charging Temperature Range: 41° to 104°F (5° to 40°C), Max Charging Power: 160. W

Table 2: Specification of DJI Phantom Pro v2 drone.

Furthermore, each drone is equipped with a Raspberry Pi 4 that has its own battery and is connected to sensors like a body thermometer, motion detection, ID scanner, a loudspeaker, and also solar energy panel for recharging the batteries while in mission.

Drones Network Architecture

The gathered data is initially processed at the drone level and then shared with upper-level systems for further detailed processing and/or database storing. In our approach, we assume to have three operational levels or layers; drone, local clinic (or base station), and general hospital levels, Figure 1 shows an overview of the proposed system architecture, which makes it scalable in a hierarchical manner as shown in Figure 2. The drone level is comprised of SDs and one LD. The SDs collect COVID-19 test data then process it and send a case status report, if the symptoms indicate that the case is infected, to the LD which acts as a swarm sink node and is connected to the local clinic level. At the local clinic level, a local clinic can run and manage multiple scanning instances in nearby areas simultaneously by deploying several drone swarms, and if any critical case is found then the general hospital is called for help. Therefore, a local clinic acts as a sink node for the drone swarms as it is connected to the general hospital. The general hospital level is the highest level, where it has the best available services for COVID-19 containment in town including specialist doctors, medical equipment and supplies, and a general database for all city residents. Also, it supervises local clinics' operations and can intervene to diagnose emergency cases reported by local clinics upon their request.

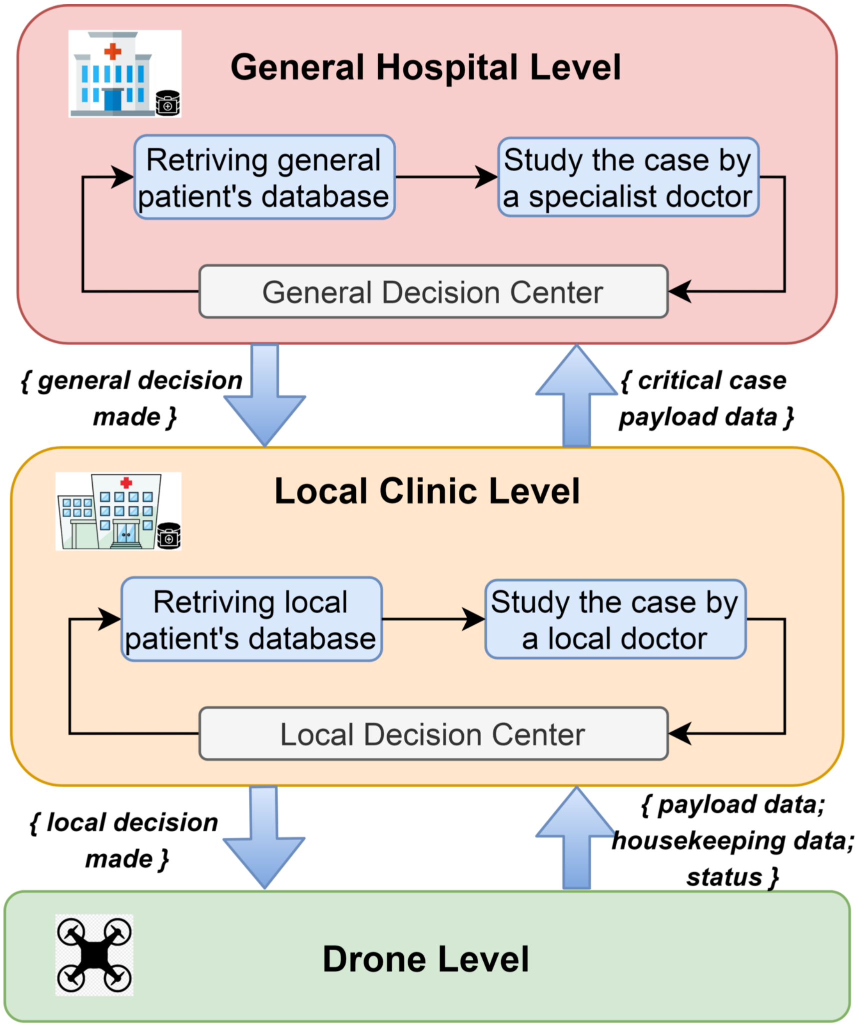


Figure 1: Overview of the system architecture.

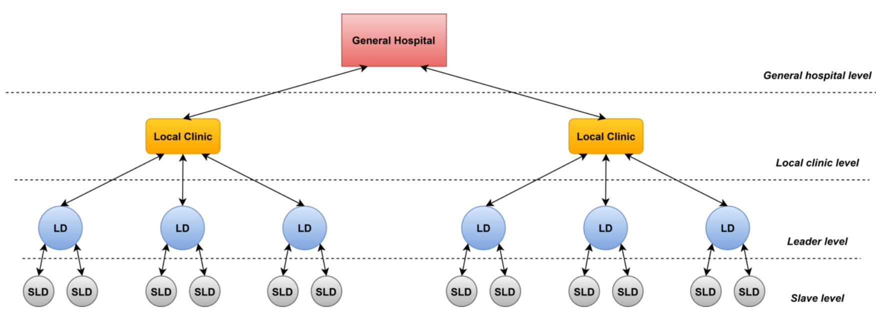


Figure 2: System layered architecture.

Key SON Functions

Improving multi-UAV network performance could be realized by implementing Self-organizing Network (SON) functions [32]. However, the decision on which SON functions to include in this paper was based on the design simplicity and low cost. Therefore, only essential and most relevant SON functions are selected and classified based on the phase of operation including:

Self-configuration SON Functions

Automatic generation of default parameters: For introducing a new host, different parameters should be assigned such as [33]: network and security parameters, e.g. Internet Protocol (IP) and server addresses and certificates. Software parameters like software version. Hardware parameters as firmware and required drivers. Radio network parameters as node parameters, neighbor relationships, transmission power, etc.

- **Network authentication:** Mutual authentication of node and network is needed during the self-configuration phase, especially when deploying new network elements [33].
- **Self-optimization SON Functions**
- **Congestion control parameter optimization:** It monitors network load, detects overload cases, measures the urgency degree of the overload conditions, and makes proper responses to get the system back to a feasible load situation in a controlled manner [33].
- **Packet scheduling parameter optimization:** Optimize resource efficiency by managing channel resource access while meeting Quality of Service (QoS) requirements [33].
- **Reduction of energy consumption:** Energy cost is one of high interest in the public, especially in drones. Therefore, energy efficiency must be considered [33].
- **Self-healing SON Functions**

Cell outage prediction: It estimates which node is a candidate for an outage and provides information about the outage expected time, likelihood, scope, and type, then reports the cell outage detection function for further processing of possible causes [33].

Cell outage detection: An outage should be detected within an adequately short time, e.g. minutes, to respond effectively. The outage detection report may include [33]: the node ID for the malfunctioned node and the type and scope of the outage.

Cell outage compensation: By autonomously adjusting network parameters to maximize performance and coverage, also fulfill mission requirements as much as possible [33].

Security Concerns

The proposed drone-based PHC system obtains residents' COVID-19 related data using drones and then transmits it to upper-level health units. Data processing, security, and privacy concerns should be considered, so a secure tunnel, that uses end-to-end data encryption, can be utilized in collecting and transmitting data as only authenticated nodes can receive the data. Status reports are sent from the drone level to the local clinic level automatically; while a manual transmission of data is done between the general hospital and local clinics. All data is transmitted using an end-to-end secure data sharing tunnel.

Redesigned PHC System for Combating COVID-19

A PHC system, shown in Figure 3, has been developed as an RHS for the COVID-19 basic test during a full lockdown, where people are not allowed to visit health centers for testing, and thus there might be suspected or already confirmed COVID-19 patients that are not aware of carrying the virus and might be spreading it to family members unintentionally. To the best of the authors' knowledge, to this day, still no scholar study the possibility of providing an automated COVID-19 testing service to the mass at their doorsteps during curfew situations with reduced human intervention, i.e. drone-based PHC platform, and report critical conditions to local/general hospitals for further investigation/reaction. The proposed approach suggests an algorithm to categorize patients' conditions to a multi-level of seriousness, and also is designed to be scalable with hierarchical distribution of roles. The main five elements of the proposed approach are:

1. The PHC payload consists of the required sensors and instructions for the testing process as well as essential COVID-19 medicine to be delivered as used when needed.

2. The multi-UAV network acts as a portable platform and transmits the needed information to the local clinic.
3. The person/patient is at home during a full curfew to be tested.
4. The local clinic with general practitioners/doctors and local medical database is also considered to be the BS for the drone swarm with a drones operator.
5. The general hospital in the city is the best-equipped place for COVID-19 containment, i.e. specialist doctors, medicine, infection control, treatment, and quarantine.

At the BS, the drone swarm, consisting of one LD and many SDs, is equipped with required testing sensors, then self-configuration is conducted. After take-off, the drones fly horizontally with a given maximum altitude to the destination area and land at the designated spot. Afterward, one approaches a SD and follows certain steps for self-testing given by the UAV and leaves the

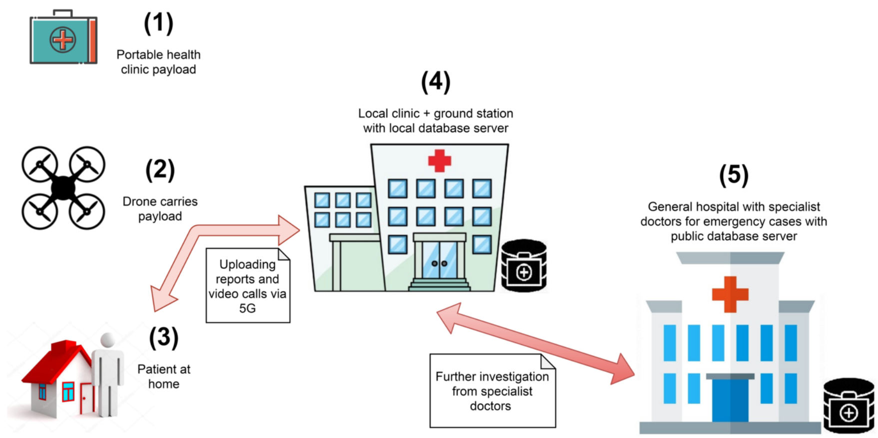


Figure 3: Portable Health Clinic (PHC) system operational procedure.

drone-landing zone, then the triage system classifies the case and if it is infected then the local clinic is informed for further investigation where the general hospital assistance might be needed, and the patient may be advised to take some medicine off the drone. When the swarm is done with one group of houses, it moves to another and the same procedure is repeated till the whole area is scanned then it flies back to the BS.

The Roles and Responsibilities of the proposed PHC System Units

The roles and responsibilities of the proposed PHC system units are distributed hierarchically for the ease of management and scalability and are described below:

5.1.1 The Local Clinic Roles:

The BS is located within the local clinic, nearby the neighborhood to be scanned, and has the drone swarm(s) as a PHC platform fully equipped with the required payload, i.e. sensors and drugs for basic COVID-19 testing and mitigation. Also, there is a drone network operator that initiates the drones with essential mission data such as Global Positioning System (GPS) coordinates, flying speed and altitude, swarm size, etc. through a dedicated server, and should always have the ability to intervene in the autonomous UAV system and manually give orders to drones as if required, e.g. abort the mission. Additionally, the local clinic has a medical staff and local patients' database, and it keeps getting periodic information about the swarm status through the LD, and if it receives a report of an infected patient, the health worker retrieves the patient's database and studies the case and either make a video call with the patient or escalate the case to the general hospital if it is urgent, contact tracing is also carried to identify potentially infected contacts. After completing the mission, the drones are disinfected and prepared again for future tours. In case of a drone failure, the BS will be reported with drone ID, last GPS coordinates, time of loss, etc. to respond accordingly.

5.1.2 The Slave Drone Roles:

The SDs generally have identical payloads and mission procedures. When a SD is selected, it updates certain parameters through the self-configuration phase including; network configuration, authentication with the LD, swarm member ID for swarm positioning, and future communications. When the swarm is ready to fly, a SD follows the LD as a reference to position itself within the swarm according to its ID to avoid colliding with other drones. When arriving, it lands according to the assigned coordinates and enters the power-saving mode by switching off unneeded functions, e.g. turning off propellers. A SD provides the LD with status reports periodically. It informs the householder of its presence and senses the person's approach through a mounted motion detection sensor. Then it gives guidance instructions for getting the required information by measuring the vital signs of a person, including the body temperature, heart rate, oxygen saturation of the blood (SpO_2), blood pressure, and respiratory rate, through recording a video for his/her face and processing the images onboard as in [34], a detailed primary screening process is shown in Figure 4.

A SD applies a COVID-19 triage process (CT-process) to the measured data to classify the case severity into four categories, as mentioned in Table 3, which are; healthy or green, suspected or yellow, confirmed or orange, and emergent or red. If the case is marked with green or yellow, then only precaution instructions are given by the SD through the loudspeaker. However, if it is labeled orange or red then it might need a doctor's consultation, so a case report is sent to the LD, which in turn sends it to the BS. Then if needed, a live video call is established between a local clinic doctor and the patient through the LD and SD. After testing, the person's ID is scanned, e.g. passport or national ID. After testing one person, a test results report is sent to the LD if it is positive. If the case requires more attention, a video call is placed between the patient and a remote doctor and is handled through the SD and LD. Then the same procedure is repeated for other family members and when all are tested, the slave drone puts itself in sleep mode, waiting for further instructions from the LD.

5.1.3 The Leader Drone Roles:

The LD first gets the required network configuration and mission information file from a dedicated server in the BS during the self-configuration process, then it authenticates the SDs to create a drone swarm. Also, it obtains an area map of GPS coordinates. Then the LD starts taking off leaving the BS followed by the SDs, and broadcasts periodic messages of its position so other SDs can calculate and position themselves within the flying swarm, and when arriving it chooses the coordinates of the center of the first street as a destination and assigns relevant GPS coordinates for each SD to land at; technically each slave drone is responsible for testing individuals of one house per sub-task.

Now, all drones are landed and the LD has almost an equal number of SDs on each side creating the least distance between itself and the furthest SD for better communication, it enters the power-saving mode by turning off unnecessary functions, i.e. turning off propellers, then collects the status reports from SDs periodically and sends a periodic swarm status report to the BS. After all, SDs are done, the LD takes off to the next group of houses to be scanned using pre-given GPS information followed by SDs, and the same process of deploying and testing starts again. Later, when the whole target area is scanned, the drone swarm returns to the BS (drone homing).

5.1.4 The Person Being Tested Roles:

During a full curfew, the people of the area to be scanned are already being informed by the media about the drone swarm visit for COVID-19 testing, so residents are expecting such a visit. When one is informed by a SD, he/she goes out on the street and approaches the SD and gets familiar with the testing procedure. Afterward, the person provides his/her vital signs and scans a document to prove the identity and leaves the drone landing area, and calls for another family member for testing if any. If the person is classified as infected or emergent (orange or red labels) then a live video call from a remote doctor is expected.

5.1.5 The General Hospital Roles:

The general hospital is considered the top-level in this approach and can supervise multiple local clinics at once. As the last resort, it should have the best available specialist doctors and medical equipment for COVID-19 treatment and containment. When an infected case cannot be handled by a local clinic it is transferred to the general hospital for further verification. The decision is made by specialist doctors based on the patient's database, current case, and available solutions to handle the case, e.g. advising the patient to be quarantined at home via a video call or sending an ambulance in case of real emergency for the treatment and quarantine at the hospital. The general hospital also performs contact tracing with keeping the privacy of the patient.

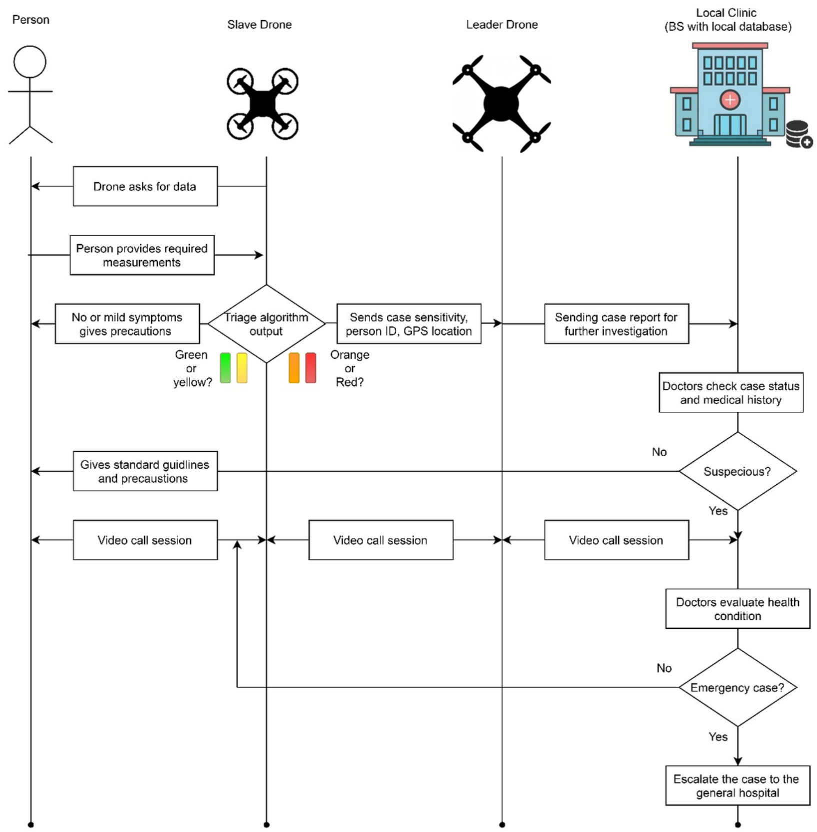


Figure 4: Primary screening and triaging process for COVID-19.

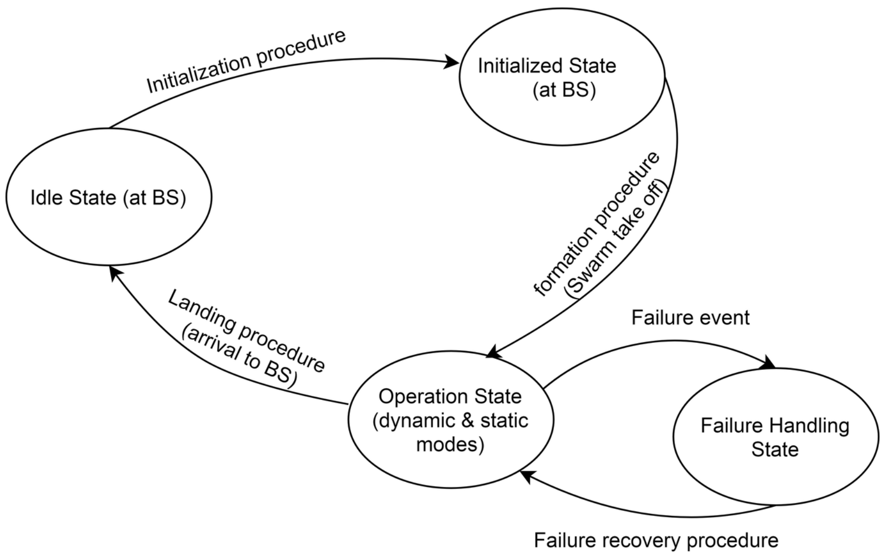
From the aforementioned roles, two operational modes can be concluded for the drone swarm, namely; the dynamic (flying) mode and the static (fixed) mode. Where the dynamic mode is when there is high network mobility during flying. On the contrary, the static mode is when the drones are landed with no mobility and entered the power-saving mode to gather required data.

Table 3: COVID-19 triage process (CT-process).

No.	Symptoms	Healthy/Green (no action)	Suspicious/Yellow (no action)	Infected/Orange (consultation)	Emergent/Red (emergency)
1	Body Temp. (°C)	<37.5	[?]37.5	[?]37.5	[?]37.5

No.	Symptoms	Healthy/Green (no action)	Suspicious/Yellow (no action)	Infected/Orange (consultation)	Emergent/Red (emergency)
2	SpO2 (%)	[?]96	[?]95	[?]95	[?]95
3	Heart Rate (bpm)	[?]76	>76 & <84	[?]85 & <90	[?]90
4	S. Blood Pressure (mmHg)	[?]71 & [?]81	[?]81 & [?]86	[?]86 & [?]91	[?]91
	D. Blood Pressure (mmHg)	[?]112 & [?]132	[?]132 & [?]142	[?]142 & [?]152	[?]152
5	Respiratory Rate (bpm)	[?]12 & [?]20	[?]20 & [?]22	[?]22 & [?]27	[?]27

5.2 The Proposed System States and Messages



To conduct model checking, explained in [35], the system was fully described as state diagrams. Figure 5 shows the main system diagrams and Figure 6 depicts the failure handling diagram.

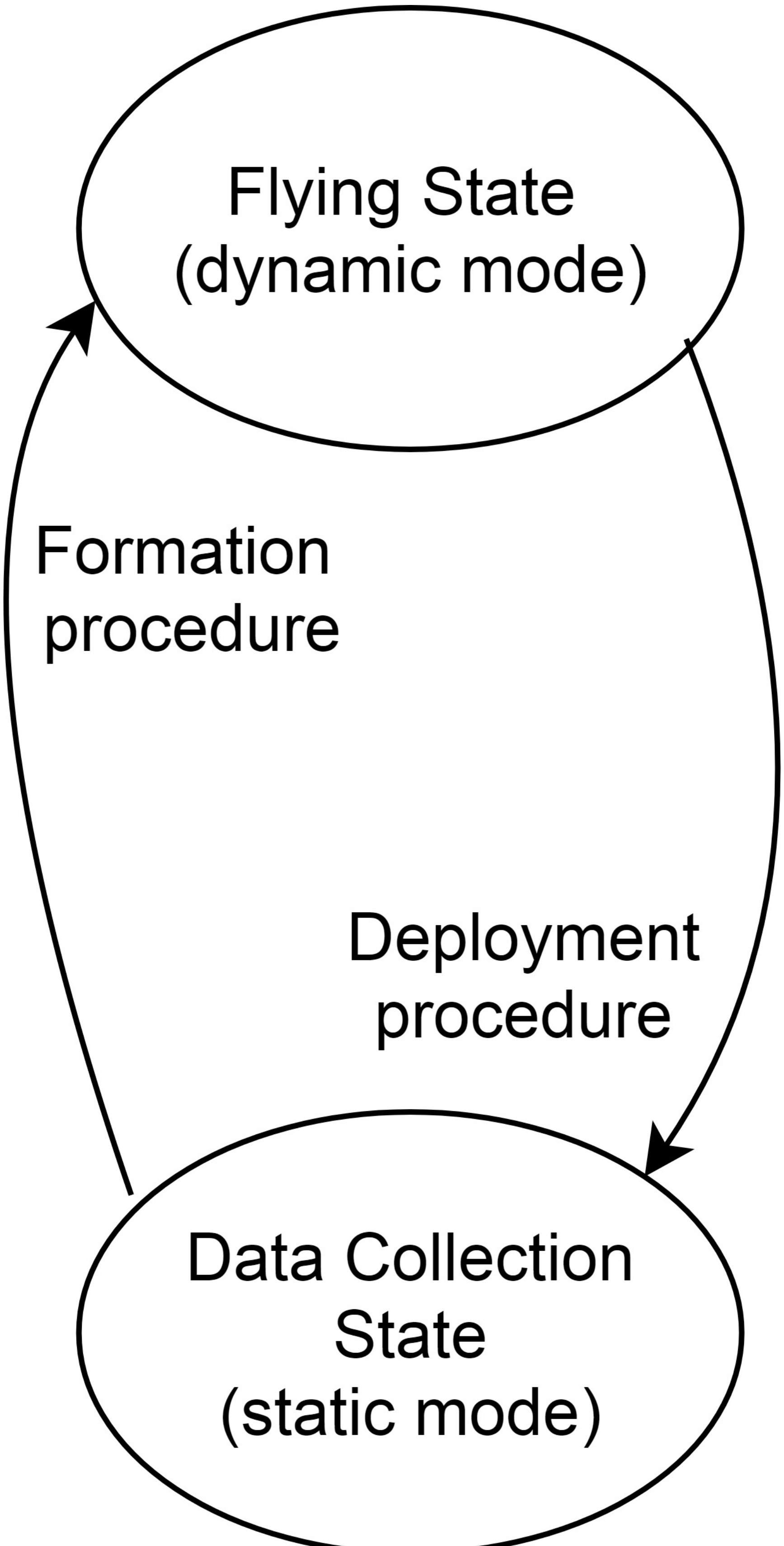

Flying State
(dynamic mode)
Formation
procedure
Deployment
procedure
Data Collection
State
(static mode)

Figure 5: Main system state diagrams: (a) System overview (b) Operational modes.

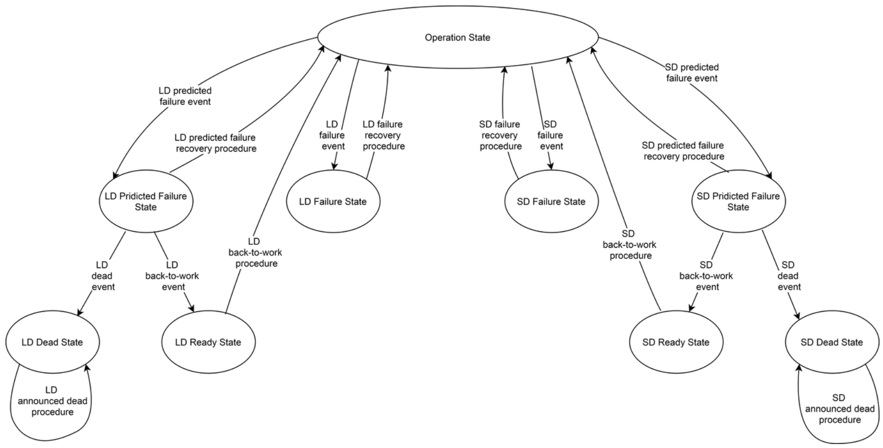


Figure 6: Failure handling diagram.

There are 18 new messages in total that are used by the proposed system are shown in Table 4.

No.	Command name	Command Contents						Comm. Size (Byte)
1	swarmReady	type	id_{UAV}					2
2	launch	type						1
3	moveToWaypoint	type	formation type	distance	z_{LD}	$(x,y)_{LD}$		13
4	land	type	id_{SD}	$(x,y)_{SD}$				10
5	$statusReport_{SD}$	type	id_{SD}	$(x,y)_{SD}$	battery level	temperature	available	13
6	$statusReport_{LD}$	type	id_{LD}	$(x,y)_{LD}$	battery level	temperature	swarm status	12+12*(n)
7	caseReport	type	id_{SD}	$(x,y)_{SD}$	case severity	Scanned ID		500
8	ack	type	id_{UAV}					2
9	$failReport_{LD}$	type	id_{LD}	z_{LD}	$(x,y)_{LD}$			12
10	connectionReq	type	id_{SD}					2
11	$preFailReport_{LD}$	type	id_{LD}	z_{LD}	$(x,y)_{LD}$			12
12	polling	type						1
13	pollReport	type	id_{UAV}	(x,y)	battery level	temperature		12
14	backReport	type	id_{UAV}	(x,y)	battery level	temperature		12
15	deadReport	type	id_{dead_UAV}	z_{dead_UAV}	$(x,y)_{dead\_UAV}$			12
16	$failReport_{SD}$	type	id_{SD}	z_{SD}	$(x,y)_{SD}$			12
17	compensationReq	type	id_{SD}	$(x,y)_{SD}$				10
18	$preFailReport_{SD}$	type	id_{SD}	z_{SD}	$(x,y)_{SD}$			12

Table 4: System messages and their format.

System Technical Specifications and Evaluation

From a technical point of view, Table 5 shows the used protocols in the proposed system.

Protocol	Abbreviation	Description
Dynamic Host Configuration Protocol version 6	DHCPv6	Automatically provides a host with network configurations, e.g. the IP address, subnet mask and default gateway.
User Datagram Protocol	UDP	Transport layer protocol
Internet Protocol version 6	IPv6	Network layer protocol
Institute of Electrical and Electronics Engineers 802.11a	IEEE 802.11a	Transmitting data over a wireless network
the Fifth Generation of cellular networks	5G	Transmitting data over broadband cellular networks
802.11e Enhanced distributed Channel Access	802.11e EDCA	Supports QoS and uses block acknowledgement to reduce traffic

Table 5: Networking protocols adopted by the system.

After the system has been described and designed, a model checking for different scenarios has taken place and the results are shown in Table 6.

Table 6: Calculated latency and throughput for each scenario.

No.	Scenario name	Data transferred (bytes)	Latency (m sec)	Throughput (Kbps)
1	Initialization Procedure	2017	22.81	707.41
2	Formation Procedure	104	6.97	119.37
3	Operation Procedure (dynamic mode)	520 (wifi) (per second)	4.2	990.48
		11 (5G) (per second)	8.53	10.32
4	Deployment Procedure	80	4.35	147.13
5	Operation Procedure (static mode)	1.5 Mega (1 sec) (wifi)	583	20.58 Mbps
		1.5 Mega (1 sec) (5G)	962	12.47 Mbps
6	LD Failure Recovery Procedure	14 (wifi)	6.35	17.64
		24 (5G)	170.57	1.13
7	LD Failure Prediction Recovery Procedure	123 (wifi)	5.23	188.15
		12 (5G)	85.29	1.13
8	LD Back-to-Work Procedure	112 (wifi)	6.4	140
		12 (5G)	85.29	1.13
9	LD Announced Dead Procedure	24 (5G)	170.58	1.13
10	SD Failure Recovery Procedure	22 (wifi)	1.45	15.17
		24 (5G)	170.58	1.13
11	SD Failure Prediction Recovery Procedure	35 (wifi)	2.21	15.84
		12 (5G)	85.29	1.13
12	SD Back-to-Work Procedure	12 (wifi)	0.91	13.19
		12 (5G)	85.29	1.13
13	SD Announced Dead Procedure	12 (wifi)	0.91	13.19
		24 (5G)	170.58	1.13

Discussion and Comparison with Other Works

During public health emergencies like the COVID-19 pandemic, deploying the PHC and other related RHS technologies in hotspot regions is helpful in terms of minimizing the risk of the virus transmission to frontline healthcare professionals and reducing their stress. Also, to avoid crowded places where there is no need for people to come in person to clinics/hospitals. Despite having so many advantages, UAV-based RHS poses challenges including [6, 11, 36]:

1. Privacy concerns: The gathered data should not be used for improper purposes.
2. Regulatory issues: Each flight should be licensed by authorized bodies.
3. Suboptimal performance: Especially when drones are fully automated.
4. Meeting performance and QoS requirements.
5. Limited energy supply: Solar-based charging system is needed to alleviate this issue.
6. Appropriate financial and human resources.
7. Sensitization of communities and stakeholders before and during PHC implementation.
8. Drone integration into the health supply chain: Should consider evaluating drone acceptability, profitability, and performance.

Table 7 shows a comparative study.

Authors	Year	System type	Features	Features	Featur
			A	B	C
Mohammed et al. [13]	2020	IoT-based drone system for COVID-19 detection		×	×

Authors	Year	System type	Features	Features	Featur
Manigandan et al. [20]	2020	Drone detection of COVID-19 with no human interventions		×	×
Soni et al. [18]	2020	UAS for consumer utilities in COVID-19 pandemic	×	×	×
Elbir et al. [17]	2020	Vehicular Network for combating the spread of COVID-19	×	×	×
Sharma et al. [6]	2021	Drone delivery dynamic models in COVID-19 hotspots		×	×
Patchou et al. [21]	2021	Drone-based efficient parcel delivery during COVID-19	×	×	×
Alsamhi et al. [37]	2021	Blockchain for multi-drone to combat COVID-19		×	×
Kumar et al. [11]	2021	Drone-based network for COVID-19 operations		×	
Proposed Work	2021	Drone swarm as a PHC in COVID-19 hotspots			

Table 7: A comparative analysis of the proposed approach with existing drone-based systems for COVID—19 response.

Features: A: Covid-19-related Data Collection, B: Multi-level Classification, C: Announcement, D: Person Identification, E: Real-time Video Communication, F: Sanitization, G: Surveillance, H: Delivery, I: Communication Relay.

Conclusions

PHC systems offer an inexpensive, usable set of portable sensors to transfer clinical data to a remote doctor to make an accurate decision. This paper mentioned relevant existing and future public health implications arising from the coronavirus spread. It presented an overview of how some drone-based initiatives have been developed to handle the situation. Our proposed PHC platform and its related methods is a leading contributor to public health responses, particularly for residents in prolonged curfews, and suggests a strong possibility of positive impact. In this paper, we redesigned the current PHC platform as a means to contain the COVID-19 spread, as well as suggested a COVID-19 triage process (CT-process), that classifies the patients on whether they need to be connected on a video call to a doctor and moved to a clinic for further inspection and treatment, by considering and analyzing the main symptoms of COVID-19, such as body temperature, heartbeat, respiratory rate, blood pressure, and SpO2. Additionally, the proposed approach allows for the delivery of essential coronavirus mitigation drugs. By achieving this, it minimizes the COVID-19 transmission risk and reduces psychological stress on frontline medical personnel, and maximizes the availability of healthcare resources to be used by patients who are most in desperate need of them.

References

[1] L. Li, Q. Zhang, X. Wang, J. Zhang, T. Wang, T.-L. Gao*, et al.* , "Characterizing the propagation of situational information in social media during covid-19 epidemic: A case study on weibo," *IEEE Transactions on Computational Social Systems,* vol. 7, pp. 556-562, 2020.

[2] W. H. Organization. (2022, 7 February). *WHO Coronavirus (COVID-19) Dashboard* . Available: https://covid19.who.int/

[3] J. Rocke, C. Hopkins, C. Philpott, and N. Kumar, "Is loss of sense of smell a diagnostic marker in COVID-19: a systematic review and meta-analysis," *Clinical Otolaryngology,* vol. 45, pp. 914-922, 2020.

[4] C. Hopkins and N. Kumar, "Loss of sense of smell as marker of COVID-19 infection. ENT UK, 2020," *Date accessed,* vol. 26, 2020.

[5] J. T. Wu, K. Leung, and G. M. Leung, "Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study," *The Lancet,* vol. 395, pp. 689-697, 2020.

[6] K. Sharma, H. Singh, D. K. Sharma, A. Kumar, A. Nayyar, and R. Krishnamurthi, "Dynamic Models and Control Techniques for Drone Delivery of Medications and Other Healthcare Items in COVID-19 Hotspots," *Emerging Technologies for Battling Covid-19: Applications and Innovations,* pp. 1-34, 2021.

[7] L. Soltanisehat, R. Alizadeh, H. Hao, and K.-K. R. Choo, "Technical, temporal, and spatial research challenges and opportunities in blockchain-based healthcare: A systematic literature review," *IEEE Transactions on Engineering Management,* 2020.

[8] S. Abir, S. N. Islam, A. Anwar, A. N. Mahmood, and A. M. T. Oo, "Building resilience against COVID-19 pandemic using artificial intelligence, machine learning, and IoT: A survey of recent progress," *IoT,* vol. 1, pp. 506-528, 2020.

[9] A. News. (2020, 29 June). *Draganfly Selected to Globally Integrate Breakthrough Health Diagnosis Technology Immediately onto Autonomous Camera's and Specialized Drones to Combat Coronavirus (COVID-19) and Future Health Emergencies* . Available: https://apnews.com/press-release/pr-globenewswire/dc01344350423d7d64c99ebbe8fb7548

[10] Z. Dukowitz, "Drones and the Coronavirus: The Many Ways Drones Are Supporting Containment Efforts in China," ed, 2020.

[11] A. Kumar, K. Sharma, H. Singh, S. G. Naugriya, S. S. Gill, and R. Buyya, "A drone-based networked system and methods for combating coronavirus disease (COVID-19) pandemic," *Future Generation Computer Systems,* vol. 115, pp. 1-19, 2021.

[12] R. Kellermann, T. Biehle, and L. Fischer, "Drones for parcel and passenger transportation: A literature review," *Transportation Research Interdisciplinary Perspectives,* vol. 4, p. 100088, 2020.

[13] M. Mohammed, N. A. Hazairin, S. Al-Zubaidi, S. AK, S. Mustapha, and E. Yusuf, "Toward a novel design for coronavirus detection and diagnosis system using iot based drone technology," *International Journal of Psychosocial Rehabilitation,* vol. 24, pp. 2287-2295, 2020.

[14] M. Kunovjanek and C. Wankmuller, "Containing the COVID-19 pandemic with drones-Feasibility of a drone enabled back-up transport system," *Transport Policy,* vol. 106, pp. 141-152, 2021.

[15] T. Mesar, A. Lessig, and D. R. King, "Use of Drone Technology for Delivery of Medical Supplies During Prolonged Field Care," *Journal of special operations medicine: a peer reviewed journal for SOF medical professionals,* vol. 18, pp. 34-35, 2018.

[16] I. H. Khan and M. Javaid, "Automated COVID-19 emergency response using modern technologies," *Apollo medicine,* vol. 17, p. 58, 2020.

[17] A. M. Elbir, G. Gurbilek, B. Soner, and S. Coleri, "Vehicular Networks for Combating a Worldwide Pandemic: Preventing the Spread of COVID-19," *arXiv preprint arXiv:2010.07602,* 2020.

[18] K. Soni and R. Gangwar, "Future Scope of Unmanned Aerial System for Consumer Utilities in Covid-19 pandemic," vol. 7, p. 9, 2021.

[19] A. Joshi, N. Dey, and K. Santosh, *Intelligent systems and methods to combat covid-19* : Springer, 2020.

[20] S. Manigandan, P. K. T. Ramesh, N. T. L. Chi, and K. Brindhadevi, "Early detection of SARS-CoV-2 without human intervention to combat COVID-19 using drone technology," *Aircraft Engineering and Aerospace Technology,* 2020.

[21] M. Patchou, B. Sliwa, and C. Wietfeld, "Flying Robots for Safe and Efficient Parcel Delivery Within the COVID-19 Pandemic," in*2021 IEEE International Systems Conference (SysCon)* , 2021, pp. 1-7.

[22] P. K. Singh, S. Nandi, K. Z. Ghafoor, U. Ghosh, and D. B. Rawat, "Preventing covid-19 spread using information and communication technology," *IEEE Consumer Electronics Magazine,* vol. 10, pp. 18-27, 2020.

[23] W. H. Organization, "Clinical management of severe acute respiratory infection when novel coronavirus (2019-nCoV) infection is suspected: interim guidance," in *Clinical management of severe acute respiratory infection when novel coronavirus (2019-nCoV) infection is suspected: Interim guidance* , ed, 2020, pp. 21-21.

[24] W. H. Organization, "Considerations in the investigation of cases and clusters of COVID-19: interim guidance, 22 October 2020," World Health Organization2020.

[25] W. H. Organization, "Infection prevention and control during health care when novel coronavirus (nCoV) infection is suspected: interim guidance, 25 January 2020," World Health Organization 9240000917, 2020.

[26] B. Heincke, R. Jackisch, A. Saartenoja, H. Salmirinne, S. Rapp, R. Zimmermann*, et al.* , "Developing multi-sensor drones for geological mapping and mineral exploration: Setup and first results from the MULSEDRO project," *GEUS Bulletin,* vol. 43, 2019.

[27] Y. Vasuki, E.-J. Holden, P. Kovesi, and S. Micklethwaite, "Semi-automatic mapping of geological Structures using UAV-based photogrammetric data: An image analysis approach," *Computers & Geosciences,* vol. 69, pp. 22-32, 2014.

[28] M. Kirsch, S. Lorenz, R. Zimmermann, L. Tusa, R. Mockel, P. Hodl*, et al.* , "Integration of terrestrial and drone-borne hyperspectral and photogrammetric sensing methods for exploration mapping and mining monitoring," *Remote Sensing,* vol. 10, p. 1366, 2018.

[29] M. Honarmand and H. Shahriari, "Geological Mapping Using Drone-Based Photogrammetry: An Application for Exploration of Vein-Type Cu Mineralization," *Minerals,* vol. 11, p. 585, 2021.

[30] DJI. (2021, 8 April). *Phantom 4 Pro V2.0 Specs* . Available: https://www.dji.com/phantom-4-prov2/specs

[31] P. Harrington, *Autonomous Drone Network: Non-Intrusive Control and Indoor Formation Positioning* : University of Northumbria at Newcastle (United Kingdom), 2019.

[32] L. Jorguseski, A. Pais, F. Gunnarsson, A. Centonza, and C. Willcock, "Self-organizing networks in 3GPP: standardization and future trends," *IEEE Communications Magazine,* vol. 52, pp. 28-34, 2014.

[33] N. Scully, S. Thiel, R. Litjens, L. Jorgueski, R. Nascimento, O. Linnell*, et al.* , "D2. 1 Use Cases for Self-Organising Networks," *http://www.fp7-socrates.eu,* 2008.

[34] F. Yang, S. He, S. Sadanand, A. Yusuf, and M. Bolic, "Contactless Measurement of Vital Signs Using Thermal and RGB Cameras: A Study of COVID 19-Related Health Monitoring," *Sensors,* vol. 22, p. 627, 2022.

[35] D. Camara, "Formal verification of communication protocols for wireless networks," 2009.

[36] UNICEF, "How Drones Can Be Used to combat COVID-19," ed, 2020.

[37] S. Alsamhi, B. Lee, M. Guizani, N. Kumar, Y. Qiao, and X. Liu, "Blockchain for decentralized multi-drone to combat covid-19," *arXiv preprint arXiv:2102.00969,* 2021.

Hosted file

`Figure.docx` available at https://authorea.com/users/475381/articles/564713-a-modified-portable-health-clinic-system-for-coronavirus-hotspot-areas

Hosted file

`Table.docx` available at https://authorea.com/users/475381/articles/564713-a-modified-portable-health-clinic-system-for-coronavirus-hotspot-areas