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RESEARCH ARTICLE

A Vehicle Social Distancing Management System Based on LiFi During COVID Pandemic: Real-Time Monitoring for Smart Buildings

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ABSTRACT The coronavirus (COVID-19) has emerged as one of the most serious issues. Researchers and officials are considering the implementation of several social distancing methods to detect potentially contaminated individuals. Nevertheless, limited social distancing methods have been discovered for tracking, scheduling, and monitoring vehicles for smart buildings. In these methods, people are tested on a regular basis in testing facilities every few days. This suggests that there may be untested infected individuals exhibiting active symptoms. Furthermore, since pandemics comparable to COVID may exhibit a range of symptoms that fluctuate throughout the day. For this reason, each time a vehicle requests entry into the facility, a real-time test or check must be performed. This study proposes a real-time vehicle social distancing decision system for managing the number of vehicles (RT-VSDD) that adds an additional testing method besides the traditional testing phase (test reports from test centers) which is a real-time vital health check during the building access request phase in order to reduce the risk of unidentified infected individuals. The concept of low-risk area and high-risk area in the building is introduced in this study where the method classifies the vehicles based on the risk levels and sends them to the targeted area. The system proposed in this study is identified as vehicle social distancing (VSD) system and is designed specifically for COVID pandemic. The performance evaluation of the proposed work has been performed using MATLAB simulations. 100 vehicles were assumed in the presented scenario with 5% untested, 20% positive, 75% negative, 30% high temperature, and 70% low temperature. When compared with the benchmark work, 40% of vehicles were classified as high risk and 55% were low risk by the proposed system, and 20% and 75% by the benchmark work. Only 5% of vehicles were denied access using the proposed system and 25% by the benchmark work. The total waiting vehicles rate was 25% and 11% in favour of the proposed work for a total waiting time of 100 minutes. The threshold value for the maximum vehicle allowed was reached 26 times by the proposed work against 13 times only by the benchmark work. 95% of vehicles were allowed access using the proposed technique, while only 75% were able to access the building using the benchmark technique. It is anticipated that the suggested system design will facilitate a reduction in the infection rate within buildings, reduces the negative economic impact, and manage the building access effectively for various industries and government sectors.

INDEX TERMS LiFi, pandemic, vehicles social distancing, smart building.

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I. INTRODUCTION

International perceptions of the pandemic disease have changed as a result of the coronavirus disease of 2019 (COVID-19), with significant implications for global health and the economy [1], [2]. The World Health Organization (WHO) reports that over 500,000 people have died and over ten million people have been confirmed to be infected in 210 countries [3].

In addition to the global health emergency, COVID-19 has caused enormous economic harm (e.g., a projected 25% unemployment rate in the US) [4]. All around the world, including Malaysia, the epidemic has disrupted network connectivity and led to variations in data rates [5]. Under such circumstances, quick action is required to stop the disease's spread, lessen its harmful effects, and allow more time for the creation of pharmacological treatments. The phrase "social distance of social distancing (SD)" describes tactics aimed at limiting the spread of illness by lowering the frequency and intensity of in-person interactions, avoiding large crowds, and maintaining a safe distance between people [6]. When used in conjunction with other non-pharmaceutical interventions, SD can effectively curb the spread of serious illnesses including COVID-19, the influenza A virus subtype H1N1, and severe acute respiratory syndrome (SARS).

Since SD reduces the likelihood that an infected person would infect a healthy person, it decreases the progression and effects of the disease. In the early phases of a pandemic, SD are essential for stopping the disease's spread. A variety of tactics can be very effective in reducing the incidence of infection and delaying the onset of the illness. Both the strain on healthcare systems and the rate of death are reduced as a result. Many nations have implemented SD measures, such as travel restrictions during the most recent COVID-19 outbreak, the closing of public spaces, and public warnings informing people to keep a 1.5–2 meters buffer when going outside [7], [8], [9]. However, implementing such large-scale projects might be challenging; for example, people still have to venture outside to get food, medical treatment, or a job because not all public spaces can be blocked off.

This is one area where technology is quite helpful to SD practices. They function, for instance, by determining people's distances from one another and warning them when they approach too closely. Even with its vast potential, SD is eventually successful when used properly. However, achieving it is not an easy task because of several challenges, including the following [10]: A large population density creates challenges because: i) some SD scenarios may have a detrimental impact on the economy; ii) some SD systems violate people's rights to privacy, data privacy, and location awareness; iii) it is difficult to modify people's behaviour; and iv) certain SD systems violate people's right to private. This article's method for solving the SD problem aims to reduce these challenges.

Several wireless technologies have made it easier to keep persons in the situations studied at a safe distance (e.g., 1.5 m). A multitude of wireless and emerging technologies have been used, according to [10], to keep distance, schedule traffic to buildings, contact tracing, crowd detection, prediction, and other scenarios. These technologies have been used in a variety of situations for a variety of purposes. However, existing models and solutions in the literature have serious privacy flaws and mostly rely on human interaction. Additionally, restricted social distancing techniques for scheduling, tracking, and monitoring automobiles for smart buildings have been found. Under these procedures, participants undergo routine testing at testing facilities every few days, and data is stored and retrieved by the system as needed. This implies that testing drivers and people every day is not practical and raises the possibility that there are untested sick people displaying active symptoms. Moreover, since COVID-like pandemics can show a variety of symptoms that change during the day, a real-time test or check needs to be carried out each time a vehicle asks admission into the facility. However, social distance has not been studied as a way to lower the number of automobiles within smart buildings that offer real-time, vital health assessments to drivers and pedestrians. In order to lower the danger of unidentified sick persons, this study proposes an enhanced version of the model presented in our previous study [11].

This study presents a real-time system, called the Real-Time Vehicle Social Distancing Decision (RT-VSDD) system, which aims to manage the number of vehicles inside a building and reduce the risk of unidentified infected individuals during the COVID pandemic. The RT-VSDD system incorporates an additional testing method, in addition to the traditional testing phase that uses test reports from test centers. This additional method involves conducting a real-time vital health check at the building access entry during access request. This study introduces the concept of categorizing cars into low-risk and high-risk areas within a building depending on their danger levels. The approach then directs the vehicles to their respective designated areas. The technology introduced in this study is referred to as a vehicle social distancing (VSD) system. The proposed system architecture is expected to successfully minimize the infection rate within buildings, minimize the negative economic consequences, and efficiently control building access for different industries and government sectors.

A. PROBLEM STATEMENT

The fundamental replica ratio (*Ro*), which indicates on median how many individuals a case (i.e., an infectious person) would infect during its entire contagious time, is one of the major parameters for SD measures selection. Various approaches have been shown to be beneficial in decreasing infection rates including i) facilities shutting procedures, ii) isolation of proven cases as well as cases demonstrating related symptoms, and iii) household quarantines. Studies have revealed that if the level of adherence is high enough, such practices can be effective. Controlling the number of people inside a building, such as a supermarket, shopping mall, or university, is the finest way to use LiFi technology in SD. Unfortunately, current SD methods make it nearly impossible to recognize and monitor individuals inside automobiles before entering buildings.

Recently, many studies have proposed various systems using different wireless and sensing technologies for fighting and reducing the spread of the COVID-19 virus. However, most of these studies considered the human factor only and no study aimed to conduct a social distancing for humans in vehicles. To fill this gap, in our previous study, [11], we proposed a system that considers social distancing vehicle where the number of vehicles are limited inside a smart building, however, the presented system has some limitations including i) infected vehicles access denial where positive tested drivers are denied access, and ii) relying on the COVID test results only for decision making. This study aims to fulfill these limitations as explained in the next sections.

B. MOTIVATION AND CONTRIBUTION

The main motivation of designing/developing a system that performs vehicle access control to smart buildings is discussed in this section, then the contribution of this research is also explained afterward. Citizens and governments find it challenging to deal with SD. There are numerous obstacles, such as establishing and maintaining a suitable distance of 1.5–2 m among individuals on all occasions, especially in the healthcare, government, and delivery services sectors. In addition, working from home [12] is not always possible since essential services must continue to run even if a pandemic occurs. Furthermore, even when SD is in operation, automobiles such as cars and motorcycles are permitted to travel in certain places such as: i) companies: especially those who provide shipping services, ii) hospitals: including ambulance and emergencies, iii) healthcare facilities: including drive-through services and medical suppliers, and iv) government: including police and military.

The recommended design in this study is created for smart buildings that encourage the adoption of technology since human interactions are significantly higher in indoors than outdoors. The implementation of LiFi technology in a novel SD system architecture for scheduling vehicle access and real-time monitoring situations is used in this study for data transmission between the building and the vehicles. LiFi technology was selected for this study over other Radio Frequency (RF) based wireless technologies because its features and specifications have been shown to exceed other technologies in terms of speed, data transfer, security, and interference [13]. There are several advantages of using LiFi technology over alternatives like WiFi, RFID, Bluetooth Low Energy (BLE), and WiFi, including security and speed.

Given the distinctive qualities of LiFi, we can see that some features—like speed—are critical to the suggested design since vehicle movement and entrance necessitate prompt data transfer.

All drivers of authorized cars are accountable for utilizing the system and adhering to certain regulations as all vehicles are registered and recognized by the organizations that would embrace the proposed system. In light of the pandemic scenario and infection control measures, for instance, drivers ought to refrain from granting unregistered or unauthorized persons access to the building through the use of their system credentials. This is because only drivers are assigned to their vehicles in accordance with safety regulations.

The suggested system architecture is seen as a real-time process and a real-time vital health examination, in which the interplay of system elements would shield it from being susceptible to manipulation by unapproved conduct. In order to maintain distance and lower the density of cars and people inside the building, this study aims to provide an efficient system design for reducing the infection rates during COVID pandemic that is primarily focused on monitoring and detecting people's symptoms in real-time while they drive. It also performs access scheduling and tracking for vehicles.

This study proposes an enhanced version of the vehicle access and scheduling method [11] where an additional testing method is added for higher reliability in order to detect infected individuals with high body temperature. The real-time temperature testing provides an additional check besides the tests from the test centers. The proposed design in this work provides an alternative solution for infected/positive status drivers wherein the infected drivers are sent to another area rather than denying their access. The infected driver's area (IDA) sends the vehicles to another area for sanitization before going inside the building. The IDA only allows the drivers to pick up and drop off services. The proposed design provides higher reliability and minimizes the infection rates. The proposed work also minimizes the loss of resources caused by the denied vehicles which can affect the economy and operations of companies and industries. The proposed work aims to solve the limitations of the benchmark work explained in the previous section.

C. ORGANIZATION

The paper is organized as follows. Section I shows the introduction, including background, problem statement, motivation, contribution, and outline. Section II explains the related works and research gab in details including the benchmark work. Section III explains the methodology, including system setup, channel models, the proposed algorithms, and the procedure and steps. Results and discussion are given in Section IV. Section V introduces the future work. Finally, the conclusion of this work follows in Section VI.

II. RELATED WORKS

Various studies have developed different systems to fight the spread of COVID-19 using different technologies and tools. The study [14] focuses on evaluating the efficacy and expenses associated with digital contact tracing (DCT) technology as a means of mitigating the spread of disease

TABLE 1. Summary of the literature review.

Studies	Social distancing	Reducing infection rates aim	Vehicles social distancing	Building access control	Infection detection method		Technology	Smart building	Implementation (performance evaluation)
					Covid-19 tests	Real-time temperature check			
[15]	✓	✓	✗	✗	✗	✓	Infrared sensor	✗	Hardware-base & Simulation
[16]	✓	✓	✗	✗	✗	✗	Smartphones, and audio waves	✗	Hardware-base
[17]	✓	✓	✗	✗	✗	✓	MQTT protocol	✗	Hardware-base
[18]	✓	✓	✗	✓	✗	✗	IoT, sensors, WSN, camera, Smartphone, NFC, and WiFi	✗	Simulation
[19]	✓	✓	✗	✗	✗	✓	IR sensors, smartphone, and WiFi	✗	Hardware-base
[20]	✓	✓	✗	✗	✗	✗	Microcomputer, WiFi, and BLE	✗	Hardware-base
[21]	✓	✓	✗	✗	✗	✗	UWB	✗	Hardware-base & Simulation
[22]	✓	✓	✗	✗	✗	✗	Video cameras	✗	Hardware-base
[23]	✓	✓	✗	✗	✗	✗	WiFi Network, and smartphone	✗	Simulation
[24]	✓	✓	✗	✗	✗	✗	mmWave Radar	✗	Hardware-base
[25]	✓	✓	✗	✗	✗	✗	UAV, and camera	✗	Hardware-base
[26]	✓	✓	✗	✗	✗	✗	Smartphone	✗	Simulation
[27]	✓	✓	✗	✗	✗	✗	Smart glasses, and camera	✗	Hardware-base
[28]	✓	✓	✗	✗	✗	✗	AI, Blockchain, CCTV cameras, and drones	✗	Hardware-base & Simulation
This work	✓	✓	✓	✓	✓	✓	WiFi, LiFi, sensors, smartphone, and cloud	✓	Simulation

TABLE 2. Summary of the comparison of the benchmark work and this work.

Studies	Problem	Method	Solution	Infection detection method		Positive/ infected users	Infection rate control	Internet connection	Pros	Cons
				Covid-19 tests	Real-time Temperature check					
The benchmark work [11]	Vehicles social distancing	Building access control	Reducing infection rates by limiting the number of vehicles inside the building	YES	NO	Denied access	Lower	Higher dependency	1. Proposed the vehicle social distancing concept for the first time. 2. Multiple access building. 3. Calculates data rates over the Vehicle-AP connection. 4. Used hybrid LiFi network at the entrance and inside the building. 5. One algorithm for less complexity.	1. Does not consider reducing vehicle waiting times nor denied access vehicles. 2. Does not have a real-time check. 3. The design suggested the waiting area is inside the building (increased infection possibility). 4. Does not allow infected vehicle to enter. 5. Only two phases process.
This work				YES	YES	Sent to the sanitization area (IDA) and process their tasks	Higher	Lower dependency	1. Considered calculating waiting times, in and out rates, building area classification, real-time temperature check, and reduces denied access vehicles. 2. Performs Vehicle classification based on risk levels. 3. Allows infected vehicle to be processed.	1. Used hybrid LiFi network at the entrance only for authentication and requests processing only. 2. Two algorithms with increased complexity with three phases. 3. Increased const.

on campus. This is done by conducting epidemic simulations using detailed empirical contact networks of both professors and students. The DCT-based technique provides a practical and highly efficient method for reducing the spread of COVID-19 in busy campuses, in comparison to traditional approaches such as class, grade, and school closures.

The study [15] introduced a real-time queue monitoring system that utilizes infrared technology. The system employed a data processing method to identify individuals in a densely populated area by detecting each region in the infrared array. The proposed method is utilized for monitoring the inter-personal spacing in queues to prevent the transmission of the COVID-19 virus, in accordance with the guidelines provided by the World Health Organization. The primary benefit of this system is in its capacity to uphold individuals' privacy while simultaneously achieving a reduced power consumption.

The article [16] outlines a technique that utilizes cellphones to enable near-field peer-to-peer connectivity. This is achieved by leveraging the existing technology to turn texts into sound waves.

Different SD scenarios were employed, as stated in reference [10]. Thus far, the prevailing applications have been focused on real-time monitoring and ensuring a safe distance, while scheduling and incentives have been utilized less frequently. In the study [17], MQTT was specifically employed to identify temperature and saturation levels. This study employs MQTT (Message Queuing Telemetry Transport) to classify individuals based on their temperature and saturation levels. MQTT has exhibited commendable mobility, dependability, scalability, interoperability, power efficiency, and security. Therefore, it can be regarded as a viable option for wireless data transmission in circumstances where social distancing and self-isolation are obligatory.

The research in [18] presents a multi-sensor Internet of Things (IoT) system designed for implementing social distancing measures in smart cities. This study aimed to develop an IoT system that utilizes a wireless sensor network (WSN), neural network (NN), and shortest path first (SPF) techniques. The system is designed to accurately identify cautions, accessible exits, gathering locations, the fairest and shortest pathways, and overcrowding. Real-time data collected by sensors and cameras is used for emergency response and monitoring purposes.

The study referenced in [19] presented Suraksha, an intelligent wearable technology designed to assist individuals with spatial disorientation during outdoor walking activities. It is a straightforward electronic device that is user-friendly. The device has the capability to monitor and record data from contacts and wellness applications using BLE technology. The study [20] developed a system for identifying suspicious individuals at university campuses by utilizing microcomputer modules and mobile hubs as access permits. A monitoring center gets data from mobile nodes.

The ‘‘6Fit-A-Part’’ protocol was introduced in [21] as a method to provide physical separation between two wearable devices in real-world scenarios. The study centered on creating a portable apparatus that emits a warning signal when detecting another sensor of the identical type within a specified distance. By employing commercially accessible UWB wireless technology, it is capable of providing precise and up-to-date distance calculations in relation to other users in close proximity.

In order to assess adherence to social distancing measures, a study in [22] presented two video-based systems for analyzing social distancing. These systems are called the automated video-based social distancing analyst (Auto-SDA) and the bird’s eye view social distancing analyzer (B-SDA). Auto-SDA is a system specifically created to quantify social separation by utilizing cameras placed at street level. In order to address the issue of privacy associated with the deployment of street-level cameras, they have made advancements in the development of B-SDA. This system utilizes bird’s eye view cameras, which ensures the protection of pedestrians’ private.

The results demonstrate the influence of social distancing policies on pedestrians’ social conduct. The research article [23] proposed a solution to the complicated issue of contact tracing for college students’ mobile behaviour trajectory. The solution involves using the campus WiFi network log and pedestrian dead reckoning (PDR) technology. It allows for the collection of student site distribution information during their daily activities on campus. However, it only considers the actual location of the smartphones in hand and does not consider other situations, such as when the smartphone is in a pocket or a purse. The solution utilizes a convolutional neural network (CNN) model to recognize landmarks in real-time PDR positioning trajectory. It then uses the particle filter algorithm to combine the PDR positioning results and detected landmarks, which helps to correct PDR cumulative error and calculate the social distance among students.

Current video detection systems are constrained by areas where objects cannot be seen, particularly in highly populated regions. The study [24] presented a novel millimeter wave radar technique for efficient management of social distancing. This solution utilizes energy accumulation and Doppler adjustment techniques to effectively minimize preprocessing interference and reliably distinguish between human and nonhuman phenomena, in contrast to conventional radar technology. By incorporating distance feedback, they have optimized the sensor setup, resulting in improved detection resolution. The methodology employed in this study has not achieved the capability to monitor all individuals in real-time, and it is possible that there could be erroneous identification of two individuals in close proximity due to the pandemic.

Due to its versatility and mobility, the unmanned aerial vehicle (UAV) is a highly promising choice for monitoring social distancing. The study [25] introduced a pedestrian identification network that is efficient and can accurately recognize pedestrians by focusing on human head detection in real-time. Additionally, it can measure the social separation between pedestrians using UAV photos.

The study [26] introduced three optimization algorithms aimed at directing human mobility and limiting the interaction between susceptible and infected individuals. The proposed solutions are based on well researched principles of network science, including clustering and homophily. In addition, they introduced a novel measure, referred to as contagion possibility, to assess the transmissibility of individuals within a social environment.

A depth camera-based distance detecting system was developed in [27] to assist administrators in monitoring social distancing across various locations. The smart glasses have been integrated into the system as terminal equipment.

The detection and warning system comprises a stationary depth camera, together with wearable smart glasses and applications. More precisely, their aim was achieved through the creation of four distinct modules: a module for detecting social distancing, a module for assessing danger, a module for providing dynamic warnings, and a module for collecting feedback.

Certain individuals are disregarding the prescribed guidelines for social separation while in motion. The study [28] proposed a strategy that combines blockchain and artificial intelligence (AI) to monitor social distancing and address COVID-19 scenarios. The suggested technique employs rapid region-based convolutional neural networks (RCNN) and you only look once (YOLO) models for detecting objects (namely humans) in real-time video streams obtained from stationary security camera systems and lens-equipped drones. In addition, an optimized algorithm for computing the Euclidean distance is implemented to measure the distance between two individuals. Blockchain technology guarantees the secure and reliable transfer of information between the entities at the physical layer and the administrative departments.

Table 1 shows a comparison of the above studies including important aspects. None of the above studies considered VSD and/or building access control with social distancing. Furthermore, in our recent study [10], a review of the most recent studies of various systems and models using different wireless and emerging technology for SD in the time of COVID-19 was presented.

In a summary, SD scenarios consider human factors only for measurements and precautions in indoor and outdoor environments and settings. To the best of our knowledge, there are very limited SD model/system that considers SD of VSD such as cars and motorbikes inside smart buildings. The recent article [29] reviewed and discussed most of the existing systems that used drones and robots for fighting the spread of the virus and reduce the infection rates. Nevertheless, no existing research has been discovered that employs drones and/or robots with the specific objective of organizing, overseeing, or restricting vehicle movement within indoor spaces or facilitating VSD.

A. BENCHMARK WORK

In our previous study [11] a novel approach has been presented that considers managing and limiting the number of vehicles in smart buildings using LiFi hybrid network where a new system design that performs real-time monitoring, tracking, and scheduling of vehicles for smart buildings was proposed for the first time in the social distancing research area. This study will be considered as the benchmark work. However, the benchmark work consists of two stages, the testing phase (Data collection), and the Detection phase (Vehicle entry). In the testing phase, users (drivers) are tested in authorized test centers. For this study, with various APs implemented at the building's gates, the number of vehicles currently inside the building can be estimated based on the data obtained at the entry permit requests that come from user devices (vehicles) towards the APs (at the gates). Reducing the infection rates in this design basically relied on the monitoring of the period of testing, However, in other SD systems, users may avoid some protocols or change their data. In addition, it is not possible for all drivers to be tested every day and they might be tested once a week. This means there are possibilities of infected individuals accessing the premises without being detected due to the unrecognized status and/or symptoms at the time of testing. Therefore, it is necessary to control vehicles access procedure with a real-time vital health check every time an access request take place at the entrance gate. Moreover, there are other challenges and limitations that will be solved in this study. Specifically, they can be summarized as follows:

1. **The internet connection challenge**: the central server that collects all the testing results (from the testing phase) needs an internet connection where all the trusted testing centers must have internet connection to be able to connect to the server to synchronize patients' data. The admin building also must have internet connection to be able to fetch all the updated information form the server. In the absence of updated data, positive individuals might access the premises without being detected. The method in the benchmark work can detect infected individuals through the test results but it won't be functional when no internet connection, and/or server breakdown.
2. **Testing rates and re-test gabs**: tests normally are scheduled weekly or when symptoms occur. This increases the chance of building access of those who are infected after their test. It also increases the cost, especially with the increase of the number of employees.
3. **Infected individuals' access deny:** when a pandemic occurs, it is inevitable to avoid being infected. In any typical social distancing technique, and in the benchmark work, positive infected individuals are denied access which means the intended business will be affected, loss of resources, and will impact the economy. So far, no study has considered an alternative solution for infected individuals other than denying their access.

Since no study that considers social distancing for vehicles in the literature except the benchmark work, the following Table 2 shows the difference between the benchmark work and this work.

III. METHODOLOGY

In this section, the proposed method is illustrated and discussed. The system design is presented and discussed including components. The proposed system aims to control and coordinate vehicles access to the building and limit the number and vehicles inside the building. The vehicle is equipped with wireless communication entities including user LiFi transmitter (UE-Tx) which is placed at the front of the vehicle, and user LiFi receiver (UE-Rx) that is placed at the roof of the vehicle. The system on the other hand, has

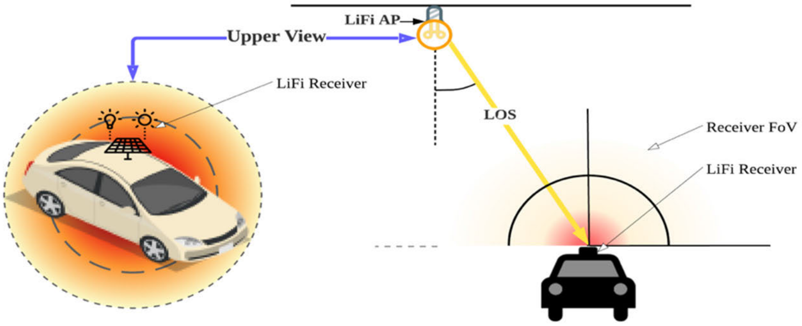


FIGURE 1. LiFi Access point illustration.

the system LiFi transmitter (LF-Tx), and system LiFi receiver (LF-Rx) that will communicate with the vehicles through downlink (DL) and uplink (UL).

Since the UL and DL gearbox are not contiguous, VL is employed for both in this system architecture. The control unit (CU) is in charge of making operational choices in accordance with the established regulations while keeping an eye on everything from within the building and recording all entrances and exits. WiFi network also exists as alternative network in case of the failure of LiFi network due to blockage or out of sight transmission. In addition, the central server (CS) is a high-speed cloud server [30] connecting all testing centers with all smart buildings. LiFi access point is shown in Figure 1. LiFi is a bidirectional, high-speed, networked wireless networking technology that employs visible light for illumination and data transport. LiFi is essentially a light fidelity that operates similarly to WiFi but utilizes a VL medium of transmission and has data speeds that are 100-1000 times higher.

LiFi technology has also progressed in terms of bandwidth, dependability, and capacity, and it now includes both a transmitter and a receiver. An RF chain converts modulated electrical impulses into radio frequency electromagnetic pulses. A modulated electrical output is converted to a light signal in LiFi networks by transmitter front-end components, and the returned optical pulses are converted to an electrical signal by receiver front-end components. Downlink transmission over IM with DD is a common feature of low-cost fragmented LiFi front ends. Transmission path characteristics downhill is altered by IM/DD.

Given that consumers are mobile, the mobility problem must be taken into account. Additionally, if the structure has more than one gate, it is possible to take into account various entrance points. To improve dependability in this situation, load balance and coordination are crucial.

A LiFi Access Point (AP) primarily serves a limited area with a radius of around 2-3 meters, meeting the spatial and coverage needs of vehicles in the restricted area of the vehicle entrance pathway. Given that the consumers are constantly on the move using mobile devices, it is imperative to take into account the issue of mobility. Since there is only one LiFi AP and one WiFi AP at each entrance, the optical co-channel interference (CCI) condition is avoided where two LiFi signals are overlapped.

Users establish a connection within the service area of a LiFi attocell. The size and brightness of the attocell are influenced by factors such as the distance between the transmitter and receiver of the AP, the height of the ceiling, and the transfer of optical energy. For a reliable connection, users of LiFi AP must be located within the coverage area of the HO circles. Users who are not using CCI LiFi APs will receive optical signals from a single LiFi AP. Each LiFi AP provides coverage for an attocell of the same size.

A typical LED chip produces only a few milliwatts of optical energy, which is considerably lower than the amount of light required for ordinary illumination. In addition, the presence of a single LiFi AP at each vehicle entrance prevents CCI with other LiFi APs. If a LiFi user experiences a lack of optical gain due to blockages or malfunction, the user will be automatically switched to the WiFi access point. The occurrence of this event is referred to as handover (HO), and when it happens between distinct wireless technologies, such as WiFi and LiFi, or vice versa, it is known as vertical handover (VHO).

Due to the utilization of distinct electromagnetic spectrums, LiFi and WiFi do not experience any interference. Hybrid networks that integrate LiFi and WiFi were developed to merge LiFi's high data transfer rate with WiFi's extensive coverage [13].

A VHO can be constructed using any mathematical method that is suitable for a function with numerous inputs and a single output. The components of the VHO procedure consist of collecting metrics, making decisions, and taking HO action. Once a good mathematical tool is chosen to represent VHO, it is necessary to evaluate the performance of the method. In homogeneous networks, usually the Signal Strength Selection (SSS) method assigns each user to the AP with the most powerful signal.

When utilising a conventional LiFi network, the user channel state information (CSI) undergoes small modifications, particularly during a handover (HO) event.

In the suggested system design, each single user is represented by a car, that will be connected to the LiFi AP before attempting to connect to the WiFi AP. To ensure connectivity and avoid the limitations of a single LiFi AP, the user can request building access through both LiFi AP and WiFi AP. This will prevent any complications that may arise from relying just on one AP. With that perspective in mind, and to prevent the aforementioned system, the user is prompted to initiate the LiFi/WiFi network pairing. The CU should oversee the system for two specific issues: when the user seeks access using an AP, and when the system encounters any difficulties, it should prompt for frame intervals. Users get allocation results from the CU and AP signals, which determine whether the network pairing process should be initiated.

Continuous monitoring of the system at regular frame intervals should be implemented by the CU. During Tp, all users receive allocation results from the CU and AP signals at constant data rates. The numerical value of the state design is represented by the variable "n". Users with a LiFi data rate above γ are assigned to LiFi APs, while those with a lower data rate are allocated to WiFi APs.

The optical channel gain of a line of sight (LOS) channel in LiFi is the measure of the strength of the signal sent across the optical medium, determined by various factors, including the Lambertian index m, the horizontal distance between a LiFi AP and the optical receiver z, the physical area of the receiver A_p, the height of the room h, the half angle of the receiver's Field of View (FOV) Θ_F, the gain of the optical filter $Ts(\theta)$, the angle of irradiance ϕ, the angle of incidence θ, and the concentrator gain $g(\theta)$, which is also determined by the refractive index, expressed as follows:

$$H = \begin{cases} \dfrac{\left((m+1)\,A_p\right)}{2\pi([z]^2+h^2)} g\,(\theta)\,Ts\,(\theta)\cos^m\,(\phi)\cos\,(\theta)\,, & \theta < \Theta_F, \\ 0, \quad \theta > \Theta_F, \end{cases} \tag{1}$$

The LED bulbs in a LiFi system operate within a limited range, transmitting signals to receivers. The following equation dictates the transformation of the median $\imath$, where the resulting optical energy P_{opt} is directly proportional to the input voltage P_t:

$$\imath = P_{opt}/\sqrt{P_t} \tag{2}$$

The conversion of electric power into optical power is determined by taking into account the standard transmitted optical power of the LiFi AP.

The Signal-To-Interference-Plus-Noise Ratio (SINR) can be expressed by taking into account the noise power spectral density N_0, the channel gain between the user and LiFi AP H (μ, α), and the efficiency of optical to electric conversion at the receivers k, and the bandwidth B:

$$SINR_{\mu,\alpha} = \frac{(\kappa P_{opt} H_{\mu,\alpha})^2}{\imath^2 N_0 B + \sum (\kappa P_{opt} H_{\mu,else})^2}, \tag{3}$$

The Shannon capacity is utilized to calculate the attainable data rate between the user and the LiFi AP by taking into account the bandwidth for optical signal transmission B_L, expressed as follows:

$$R^{(n)}_{\mu,\alpha} = \frac{B_L}{2} log_2(1 + SINR^{(n)}_{\mu,\alpha}, \tag{4}$$

RF utilizes orthogonal frequency-division multiple access (OFDMA). The estimation of WiFi channel gain takes into account many factors, including the straight lane falling channel h_d, the Rician component for internal 60 GHz connections $K = 10$ dB, the scattered path fading channel $h_s{\sim}C\,\mathcal{N}(0,1)$, and the large-scale fading loss in decibels at the isolation range $L(d)$:

$$h = \sqrt{10\frac{-L\,(d)}{10}} \left(\sqrt{\frac{K}{1+K}} h_d + \sqrt{\frac{1}{1+K}} h_s \right), \tag{5}$$

The allocation of bandwidth acquired by the user and the increase in WiFi capacity are also taken into account, expressed as WiFi data rate:

$$\Upsilon^{(n)}_{\mu,\alpha} = B_\mu log_2 \left(1 + \frac{\left[h^{(n)}_{\mu,\alpha} \right]^2 P_R}{N_0 B_R} \right) \tag{6}$$

where $h^{(n)}_{\mu,\alpha}$ is the WiFi channel gain, and B_μ is the bandwidth specified to the subscriber μ in the WiFi system. The transmission effectiveness between two neighboring states can be expressed as follows:

$$\eta_{ij} = \begin{cases} 1 - \left[\dfrac{t_{ij}}{T_p} \right] & i \neq j, i, j \in C_{\mathcal{L}} \cup C_{\mathcal{R}.} \\ 1, \quad i - j \end{cases} \tag{7}$$

where the procedure $[.]^+$ stands for maximum (., 0). The serving AP in state $n-$ 1 for user μ is signified as α_μ. To wholly utilize LiFi's spatial-spectral efficiency, users would be assigned to LiFi APs first in each state. The LiFi AP obtaining the greatest connectivity data rate with HO can be expressed as follows for users:

$$\beta_{1,\mu} = argmax \quad \eta_{\alpha'_\mu j} R_{\mu,j}. \quad j \in C_{\mathcal{L}} \tag{8}$$

where $\eta\alpha'_\mu j$ is the transmission efficiency of the linked LiFi user in the following state n, $\beta_{1,\mu}$ is LiFi AP with the highest communication link data rate with HO, and $R_{\mu,j}$ is the attainable LiFi data rate in the next state. The optical data rate $\Omega\mu$ for every user can be composed by considering the different factors including the values in eq. (7), (8), and users served by the LiFi AP.

$$\Omega_\mu = \eta_{\alpha'\mu} \beta_{1,\mu} \frac{R_{\mu,\beta_{1,\mu}}}{M_{\beta_{1,\mu}}}, \tag{9}$$

Therefore, users that obtain a data rate higher than the γ, $\Omega\mu < \gamma$, can be assigned to the LiFi, otherwise, it will be assigned to the WiFi AP. As per (8) and (9), the AP assigned to subscriber μ in state n can be written as follows:

$$\alpha_\mu = \begin{cases} R^{(n)}_{\mu,\alpha} & \Omega \geq \gamma \\ \Upsilon^{(n)}_{\mu,\alpha}, & \Omega < \gamma \end{cases} \tag{10}$$

TABLE 3. Variables used in Algorithm 1 and 2.

Term	Meaning	Term	Meaning
V	Vehicle (user)	HR_a_Vin	Total V entered the high-risk area
Vin	Total entered V	HR_a_$Vout$	Total V exited the high-risk area
$Vout$	Total exited V	n	A state (*time*)
V_new	New V	Ns	Total set of n
Vsh	V threshold value	TR	Test results
V_wtg	Waiting V	TR_ptv	Positive test result
LR_a; HR_a	Low-risk area and High-risk area	TR_ntv	Negative test result
LR_a_Vsh	Low risk area threshold	LT; HT	Low temperature and High temperature
HR_a_Vsh	High risk area threshold	LR_V	Low-risk V
LR_a_Vin	Total V entered the low-risk area	HR_V	High-risk V
LR_a_Vout	Total V exited the low-risk area		

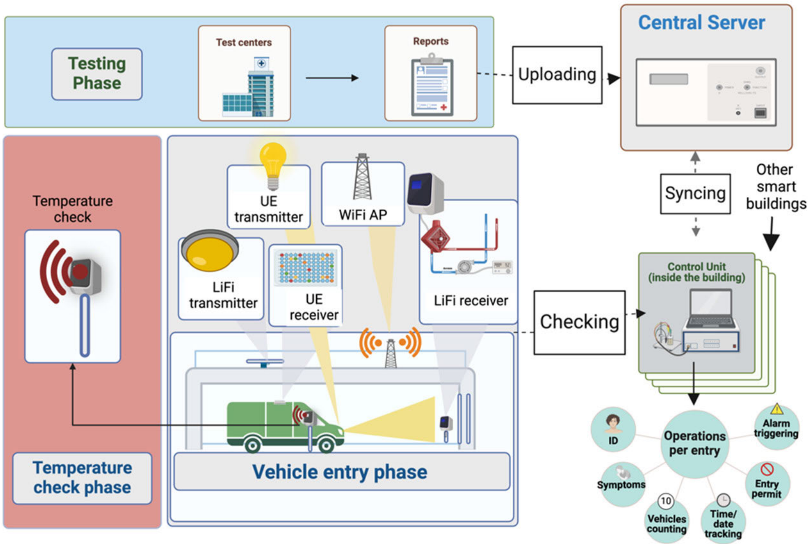


FIGURE 2. Illustrations of the proposed real-time monitoring, vehicle tracking and scheduling system for smart buildings.

$R^{(n)}_{\mu,\alpha}$ can be replace with $\beta_{1,\mu}$ in case there are multiple LiFi APs at the entrance. The vehicle exchange information to/from the system through the wireless connection of the LiFi and/or WiFi network. In order to increase user data rate capabilities and get around LiFi LOS obstructions, the WiFi network is introduced to the system. A connected LiFi user is moved to the WiFi AP if there is no optical gain due to obstructions or malfunctions of any kind.

Government policies are the major factor influencing local firms' adoption of the suggested model. The user will be required to enter their car plate information and mobile phone number throughout the enrolling procedure. It is expected that the suggested design, which will be installed in a smart building, would significantly reduce the danger of infection.

There are several requirements for the proposed design. The system components that came with the car that allowed entrance to the smart building must first be installed, and the drivers must have training. The following is an explanation of the three phases:

1. **Testing phase (Data Collection)**: test sites will gather main data on COVID-19 participants throughout this phase. Basic information including address, occupation, vehicle plate number, and current mobile phone number(s) should be gathered when an individual enters a COVID-19 test facility.
   The COVID-19 test result, whether positive or negative, will be submitted to the central database together with the previously recorded information. A notification can be sent to the driver through the phone app from the test center.
2. **Temperature check phase (health check):**when the vehicle approaches the entrance, the system asks the driver to record their temperature using the temperature sensor near the gate. This check represents the real-time health monitoring check where the user with high temperature will be classified as high-risk vehicle, while low temperature drivers will be classified as low-risk vehicles. Drivers that are marked with infected/positive status from the health tests (from the test centers) will also be marked as high-risk vehicles even when their temperature is normal (not high). A notification can be sent to the driver through the phone app at the time of temperature check in real-time.
3. **Vehicle entry phase:** the vehicle sends an access request to the system at the gate of the building including user data and vehicle information with the

health data. Access points are paired with the vehicle at this point and disconnected at the time of exit from the building. Generally speaking, both the UE and LiFi receivers are in listening mode when the car gets close to the building's entrance gate.

Upon detecting LF-Tx signals, UE-Rx gets instructions. When a vehicle approaches, a message with instructions will show on the driver's phone screen, prompting them to take the next action. The proposed system design consists of three phases as shown in Figure 2. All the details of the vehicle entry request are shown in Figure 3.

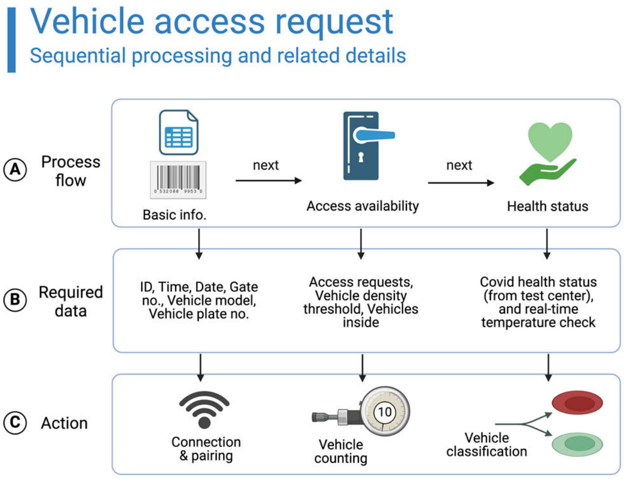


FIGURE 3. **Vehicle entry request steps and related information.**

Upon detecting LF-Tx signals, UE-Rx gets instructions. When a vehicle approaches, a message with instructions will show on the driver's phone screen, prompting them to take the next action. The instruction consists of two requests: one for information transmission and the other for entrance access (this operation is analogous to tapping a card in a typical system). Transmitting data from UE-Tx to LF-Rx may resemble the idea presented in [31]. With the assistance of the CS, the transferred data will be instantly checked and examined.

The components in Figure 2 shows that there are three primary operating stages in the overall system architecture. Every phase has a distinct set of tasks. Further information about the stages and their activities is provided below.

In this proposed design, the vehicle access request process goes through sequential steps. First, the system collects basic information. Second, the symptoms of drivers are checked for vehicle classification including test results and real-time temperature check. Third, the number of vehicles is checked for keeping limited access to the building.

In this proposed design, there is no access deny for infected individuals and/or high-risk vehicles. Low-risk vehicles are allowed to access the building and conduct their business normally. On the other hand, high-risk vehicles are sent to separated area where they are treated differently with more cautious. Based on the obtained data from phase 1 and 2, the vehicles classifications are done, and the classification is shown in Figure 4. The available options in the diagram are before considering the third phase.

After the vehicle classification, the system checks the number of vehicles inside the building, before granting access to the vehicle. When a violation occurs, such as when the number of cars within the facility reaches its limit, an alert is sent off, and fresh directives are issued. Depending on the size and capacity of the building, different locations allow for different numbers of cars within; this number must be chosen during system setup. The vehicle (V) is allowed access when there is no violation, and the vehicle count can be updated when the vehicle enters or leaves the facility using a particular procedure. The system will prevent entrance and urge the customer to return later if the maximum number of cars is reached (the waiting time may be defined depending on capacity and some other criteria based on the operations and processes within the building). Since no personal information will be disclosed to other parties, users' privacy won't be jeopardized. Moreover, location data will not be required by the system.

The processes and steps for our proposed system are introduced in Algorithm 1 and Algorithm 2. Algorithm 1 consists of connection establishment, monitoring, log-in and records, incoming requests monitoring and responding, data exchange, vehicle counting, building capacity monitoring. This includes basic information collection and limiting vehicle entry based on the vehicle density inside the building which means the vehicle threshold Vsh is being monitored by algorithm 1. This is related to the threshold value that refers to the maximum number of vehicles allowed in the premises. This can be set and determined by system administrator based on the size and type of activity of business. If the building reached the maximum number of allowed vehicles, the system ask the driver to come back later and/or wait for a while. A waiting area can be designed and included in the process of the system to coordinate and manage the waiting times and process where a scheduling technique can be used for this purpose. The whole scheduling technique that is created and provided in this study is formulated as Algorithm 3.

On the other hand, Algorithm 2 consists of few operations including establishing an entry after satisfying the condition where the building has not reached its maximum number of vehicles (calculated and monitored by Algorithm 1). In case the building is not fully occupied, the vital health check process starts including checking the health status for vehicle classification where low-risk vehicles are sent directly to the main area of the building, while high-risk vehicles are sent to the sanitation area and only allowed for pick-up and drop-off service.

According to the process shown in Figure 4, if the test results from the test center is positive, then the vehicle will be marked as high-risk vehicle. On the other hand, if the result is negative, the system checks the real-time body temperature of the driver, if it is lower than 37.5, the vehicle will be marked as low-risk vehicle, otherwise it is considered a high-risk

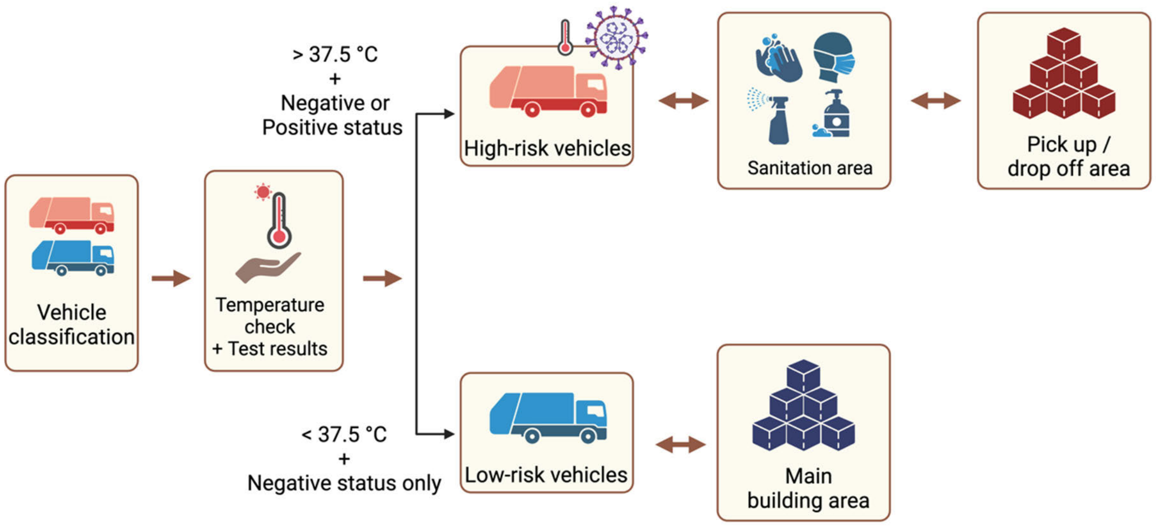


FIGURE 4. **Vehicle entry classification by the temperature check and test result.**

vehicle as the temperature is higher than 37.5. Algorithm 1 is responsible for counting the vehicles in and out the area and sends an update every time a vehicle goes in or out the gate.

The process in Algorithm 1 is performed prior to vehicle entry, while the process of Algorithm 2 mainly operating during and after the initialized of vehicle entry. The first algorithm operates in all times while the second algorithm operates once in each state for each vehicle entry. The following are some highlights of the procedure and details of both algorithms.

Upon system initialization, RT-VSDDcommences. Key responsibilities include configuring a functional system, activating all necessary components, and detecting all available entry points. The suggested method comprises multiple steps and can be summarized as follows:

As the system starts, all the related variables are set where V_new represents the new user (vehicle V). The system monitors the total V entering and exiting the building where the two variables Vin and Vout refer to the total number of vehicles that went inside the building and exited, respectively. As Algorithm 1 is the main part of the system, it starts tracking and monitoring operations all the time. The presented technique mainly aims to limit the number of vehicles inside the building based on a threshold Vsh value that represents the maximum allowed vehicle in the premises. This threshold can be set by the administrator based on various factors, it can be any number from 3 to 10 or more.

The building is divided into two areas, the low-risk area, and the high-risk area so that the vehicles that are identified as low-risk V are directed and sent to the low-risk area, and high-risk Vs are sent to the high-risk area based on the classification that is done by Algorithm 2. Each area has separate space, and vehicles are counted separately and can has a separate threshold value. After obtaining the health status and V classification from Algorithm 2, Algorithm 1 makes a decision for allowing entrance to the determined area or denying the entry if the number of V reached Vsh (reached maximum allowed value), the V_new will be marked as waiting vehicle V_wtg. The total number entering and exiting each area are also counted and monitored. All the variables considered in the system and used in the proposed algorithms 1 and 2 are shown in Table 3.

A. PROCEDURE AND STEPS

After setting all the variables and the system is ready and in a listening mode, arrived vehicles at the entrance V_new are detected as the user sends an entry request using the UF_Tx that is attached at the front of the V wherein data are sent to the sensor at the gate, LF_Rx that represents the system side. A connection is initialized, the system pairs the V with the access point AP (LiFi or WiFi) and the V is verified and authorized for further process.

The steps 2-6 in Algorithm 1 shows the connection and pairing process. Specifically, when an entry request arrives (step 3), the channel state information (CSI) is obtained with the paired V and the AP (step 4). In (step 5) all necessary information is exchanged, and the paired V is identified as V_new_i where i represents the current user counter. Before proceeding to the main process of checking and classification, the system updates the total number of V entered and exited the building.

After a request is received by the system, the main factor for making a decision to allow vehicles to enter the building is the availability where the threshold of the maximum number of allowed vehicles is checked. Before checking the availability, the health status of the vehicle is checked based on the test result that comes from test centers and the body temperature of the driver is checked and used to classify vehicles using algorithm 2. In (step 7), algorithm 1 calls algorithm 2 for conducting the vehicle classification.

Through steps 8-19 of algorithm 1, the system checks whether the current vehicle under consideration is a high-risk vehicle HR_V, and belongs to the high-risk area HR_a, if yes, then the system checks the number of V (HR_a_Vin) inside that area and compare it with its threshold value. If the condition is met, the V_new_i is sent to the targeted area. After the V successfully enters the targeted area, a notification is sent from the system to the user (phone application) and to the admin. In (step 11), an update of the V inside that area is sent to the system including the new V, HR_a_Vin++, and the total number of V inside is also updated as in (step 12). Then the current V, V_new_i marked as existing V in the HR area, denoted as HR_exist_i (step 13). On the other hand, if the threshold value already reached its maximum value, the V_new_i is denied access Vden (step 15), marked as waiting V, V_wtg_i, and asked to wait until a space is available (step 16). The waiting list is updated (step 17).

Furthermore, on the contrary, if the V_new_i is a low-risk vehicle LR_V, the V is sent to the low-risk area LR_a, and the process for the HR_V (steps 8-19) is repeated but for LR_V (steps 20-31). When a new V requests an entry, *new_entry_request*, steps 3-32 are considered. After that, each vehicle inside the building will be given a specific time to exit the building, and that time is set to 10 minutes (steps 33-40), where Tr is the timer (which is also denoted as V_{SD}), and TrX is the variable that is 10 minutes. When the vehicle inside the building V_exist_i reaches the destination inside its area, the timer is activated and assigned to the vehicle, and the vehicle V_exist_i becomes V_new_d (steps 34-39), where the vehicle can roam up to 10 minutes before request exit.

While steps 41-48 are considered for V sending an exit request, *new_exit_request*, and about to leave the building where the related variables are updated as Vin–, Vout++, HR_a_Vin– when the V_exist_i is identified as HR_exist_i, and variables Vin–, Vout++, LR_a_Vin– when the V_exist_i is identified as LR_exist_i.

After all the process of one cycle of one V is finished, the interval state (n) is updated and moved to the next as the system starts to be listening mode again as new V is expected to arrive. All details and steps of Algorithm 1 are shown in Figure 5.

The process of V classification based on the health status is presented in Figure 6, as all the steps and details of algorithm 2 are shown. As a new health check request initiated, algorithm 2 starts. While the V_new_i has a record in the test centers and has gone through a test as scheduled based on the regulations, the system starts the health check (steps 2-20), otherwise, the V_new_i will be denied access Vden (steps 21-23) and will be asked by the system to update their TR status by visiting the authorized test center and make the test as planned. In this algorithm, there are two types of health check, the test results TR obtained by the test centers and the real-time body temperature check. Summarized as follows:

1) **First health check process:** this process operates in step 4 to step 18. The TR of that particular V, V_new_i, is fetched and compared against the ID and V plate number. The test results either positive TR_ptv, or negative TR_ntv. If the V_new_i is recognized as positive (step 4), the V is marked infected and considered as high-risk V, HR_V (step 5), and the V will be included with the total vehicles that belong to the HR_a (step 6). In this case there is no need for checking the body temperature because the V is already considered as infected and marked as high-risk V. That means the next process of body temperature check only begins if the TR of the V_new_i is marked as negative, $V\_\text{new}_i == TR\_\text{ntv}$, (step 8).
2) **Second health check process:** this process operates in step 9 to step 17. The temperature sensor receives an execution order, and the driver receives a notification on the phone app that is sent by the system to proceed for the body temperature process. In case the body temperature is high, denoted as HT, approximately equals 37.5 or higher, the V_new$_i$ is marked as HR_V, otherwise it is marked as LR_v with low temperature, denoted as LT, and the related variables are updated in either situation.

Figure 7 illustrates the sequential progression of the process flow, encompassing all the phases outlined in algorithms 1 and 2. A vehicle symbolizes the user in this dynamic system. All sensors in the vehicle, including LiFi and WiFi APs, are connected to the driver via BLE via a smartphone app, allowing the driver to initiate and send an entry request once reaching the gate, check his COVID test results, connection status, entry history, and more. After pairing with the smart building's AP(s), the car will be connected to the system and disconnected when it departs the service area. After pairing the devices, the user sends and receives information from the car and gate.

As well as the entry request, the driver will be advised of any medical updates and the system will assess if the user can enter, wait, or be rejected. The driver can contact the building admin via the app. The Gate side is crucial for sending and receiving data between user nodes and the system. High-speed data collection improves decision-making performance and latency. All gate entities connect users to the building control unit for easy monitoring and tracking. Any entry or access point assignment event should be reported to the user and the CU.

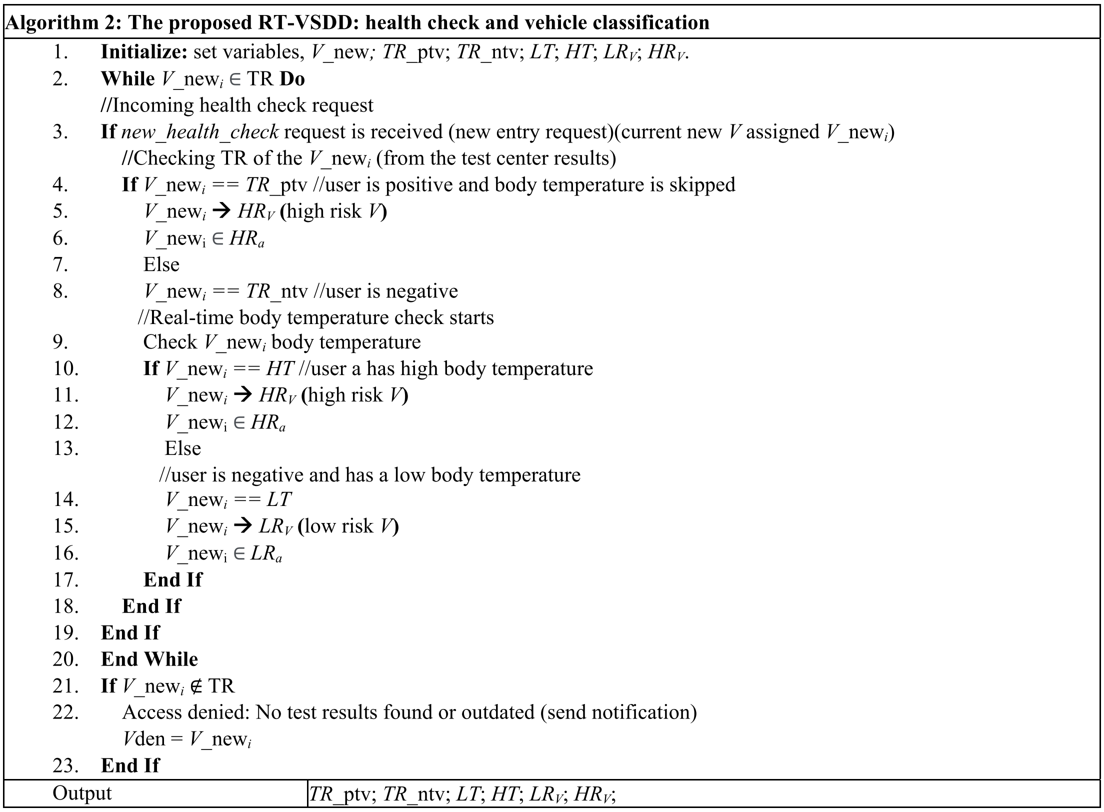
On the building side, this device controls vehicle access, support, announcements, and monitoring and tracking. The administrator has full control over system data, user accounts, and supervision. The gate and cloud server APs help this unit perform the user APA process. The number of cars within and outside the building is determined based on the status of users inside the building and their AP connections, which is measured by the calculations done by the system every time a V goes in and out. The system also verifies COVID test results and measuring the temperature where necessary before making a choice by regularly connecting to the could server where all drivers' health assessment results are maintained. For log tracking, the CU sends all

Algorithm 1: The proposed RT-VSDD: tracking, log-in and log-out monitoring

```
Booting: set variables, $V\_new$; $V$in; $V$out; $V\_wtg$; $LR_a\_V$sh; $HR_a\_V$sh; $LR_a$; $HR_a$; $LR_a\_V$in=0; $LR_a\_V$out=0;
$HR_a\_V$in; $HR_a\_V$out.
While (($n \leq Ns$) && ($V$ to AP connection is paired and secured using the hybrid LiFi/WiFi network, eq. (10)),
Do
//monitoring and listening
If new_entry_request is received (new vehicle detected $V\_new$)
  Obtain CSI for the connected vehicles and APs
  Obtain and exchange information from $V\_new_i$
  Update information and vehicle count $V$in, $V$out
  //checking health status and classifying vehicles
  Check vehicle health status, and classify vehicles using Algorithm 2
  //checking space and availability
  If $V\_new_i \in HR_a$
    If $HR_a\_V\text{in} < HR_a\_V\text{sh}$
      Send $V\_new_i$ to $HR_a$ (open gate and send notifications)
      $HR_a\_V$in++ (update $V$ inside the $HR_a$)
      $V$in++
      $HR\_exist_i = V\_new_i$
      Else
      Access denied: the vehicle is marked as waiting $V$.
      $V\_new_i = V$den; $V$den++
      //set the $V$ as waiting
      $V\_wtg_i = V\_new_i$
      $V\_wtg$++
    End If
  End If
  If $V\_new_i \in LR_a$
    If $LR_a\_V\text{in} < LR_a\_V\text{sh}$
      Send $V\_new_i$ to $LR_a$ (open gate and send notifications)
      $LR_a\_V$in++ (update $V$ inside the $LR_a$)
      $V$in++
      $LR\_exist_i = V\_new_i$
      Else
      Access denied: the vehicle is marked as waiting $V$.
      $V\_new_i = V$den; $V$den++
      //set the $V$ as waiting
      $V\_wtg_i = V\_new_i$
      $V_{WL}$ ++
    End If
  End If
End If
While ($V\_new_i == LR\_exist_i$ || $V\_new_i == HR\_exist_i$)
  If $V\_new_d$ == True // the vehicle reached the destination
    //Timer is assigned: mark and notify the vehicle for exiting the building.
    $V_{SD}$ = Tr$X$
    $V\_new_d = V\_new_i$
    $V\_new_d \leftarrow$ Tr$X$ // a timer is assigned to the vehicle
    $V\_new_i^{TrX} = V\_new_d$
  End If
End while
If new_exit_request is received (existing vehicle exit request)
  If $V\_new_i == HR\_exist_i$ //$V$ is exiting from high-risk area
    $V$in--, $V$out++, $HR_a\_V$in--
    Else
    $V\_new_i == LR\_exist_i$ //$V$ is exiting from low-risk area
    $V$in--, $V$out++, $LR_a\_V$in--
  End If
End If
Refresh and update all variables before the next state
n $\leftarrow$ n+1.
End While
```

Output	Vehicle in (Vin) Vehicles out (Vout) High risk vehicle in (HR_a_Vin) High risk vehicle out (HR_a_Vout) Low risk vehicle in (LR_a_Vin) Low risk vehicle out (LR_a_Vout) Waiting vehicles (V_wtg)

FIGURE 5. The proposed RT-VSDD: Algorithm 1.



Algorithm 2: The proposed RT-VSDD: health check and vehicle classification

```
Initialize: set variables, $V\_new$; $TR\_ptv$; $TR\_ntv$; $LT$; $HT$; $LR_V$; $HR_V$.
While $V\_new_i \in TR$ Do
//Incoming health check request
If $new\_health\_check$ request is received (new entry request)(current new $V$ assigned $V\_new_i$)
    //Checking TR of the $V\_new_i$ (from the test center results)
    If $V\_new_i == TR\_ptv$ //user is positive and body temperature is skipped
        $V\_new_i \rightarrow HR_V$ (high risk $V$)
        $V\_new_i \in HR_a$
        Else
        $V\_new_i == TR\_ntv$ //user is negative
       //Real-time body temperature check starts
        Check $V\_new_i$ body temperature
        If $V\_new_i == HT$ //user a has high body temperature
            $V\_new_i \rightarrow HR_V$ (high risk $V$)
            $V\_new_i \in HR_a$
            Else
           //user is negative and has a low body temperature
            $V\_new_i == LT$
            $V\_new_i \rightarrow LR_V$ (low risk $V$)
            $V\_new_i \in LR_a$
        End If
    End If
End If
End While
If $V\_new_i \notin TR$
    Access denied: No test results found or outdated (send notification)
    $V$den = $V\_new_i$
End If
```

Output	TR_ptv; TR_ntv; LT; HT; LR_V; HR_V;

FIGURE 6. The proposed RT-VSDD: Algorithm 2.

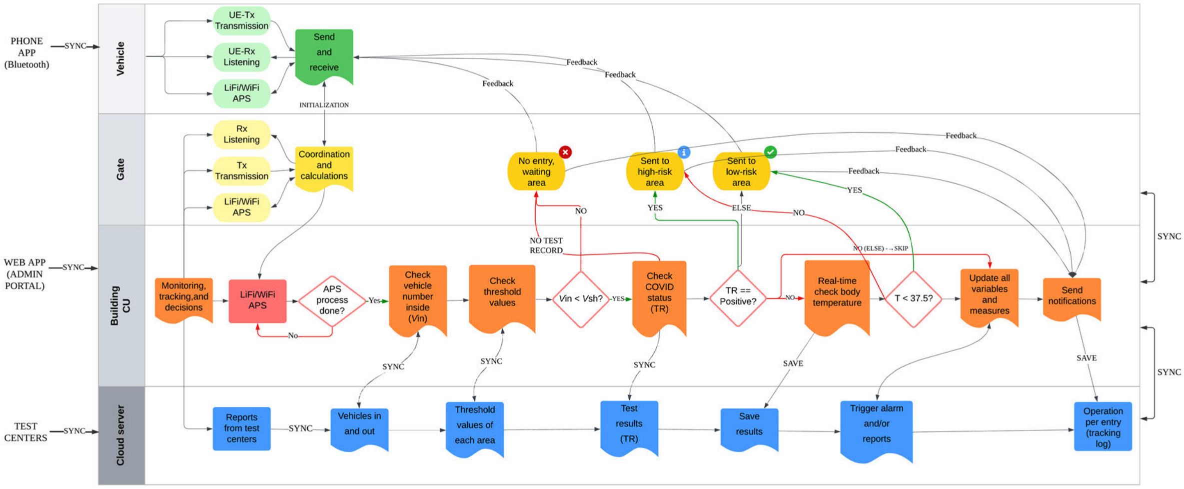


FIGURE 7. System model process.

commands to the gate side and main server. The system triggers an alarm and sends it to the targeted area. If a positive case is detected at entry request or test results, the system admin notifies the devoted area and its staff. The cloud server helps the CU decide. Cloud storage successfully stores patient data. Patients must submit usernames and passwords to view their data. Patient data synchronization to the medical database, which can store a full copy of the remote server's data, is crucial to cloud storage. The cloud medical database and repository sync client status changes. The cloud stores static and dynamic patient data. Due to authentication and authorization, only the patient can access cloud repository data. Cloud storage and access encrypt and decrypt data. The government, healthcare agencies, and doctors collect all patient data to control COVID-19. This data helps doctors and researchers investigate and treat patients.

With the classifications, checking, and monitoring, the vehicles are scheduled based on the conditions and settings in the main algorithms. In addition, all vehicles are being scheduled and coordinated to achieve the main objective of limiting and controlling the density of vehicles inside the building. Therefore, the main steps and details of scheduling process is presented below in Algorithm 3.

The system manages the scheduling and access control of vehicles entering various sections of a facility, taking into account their health condition and the density of vehicles. Summarized as follows:

A. **Core Algorithm Steps**: Defining the vehicle attributes. There are 100 automobiles categorized based on their COVID status (positive, negative, or no test) and temperature (high or low). Next, overseeing the areas and capacity. The proposed work consists of two distinct zones, namely high risk and low risk, each zone is capable of accommodating a specific number of cars.
B. **Access Control and Area Assignment**: Vehicles are categorized as either high risk, indicating they have tested positive for COVID19 or have a high temperature, or low risk, indicating they have tested negative for COVID-19 and have a low temperature. Vehicles endeavor to access their allocated zone (high risk or low risk). When the area reaches maximum capacity, individuals are added to a queue to wait for availability. Access is forbidden for vehicles without a test result.
C. **Threshold Management**: Once either the high risk or low risk region achieves its maximum capacity, a threshold is said to have been reached. A car is allotted a specific amount of time to leave the premises and be relocated outside the occupied area in order to create available space, after which waiting vehicles are then relocated into the vacated area.
D. **Processing Over Time**: Every minute corresponds to a vehicle making an effort to enter the structure. The status of vehicles and waiting list is continuously updated in real-time. Multiple indicators, including the count of cars refused entry, attainment of area thresholds, and waiting durations, are monitored, recorded, and reported.
E. **Scheduling and Management**: The primary scheduling process ensures that vehicles are allocated to suitable locations based on health criteria. Threshold management mechanisms aid in regulating the flow of vehicles and preventing over capacity. Vehicles that are not allowed entry or are placed on waiting lists are managed in a manner that ensures the building's capacity and safety measures are maintained.

This technique offers a systematic approach to overseeing and evaluating vehicle access control in different health conditions, enabling the comparison of various management solutions. The main steps of scheduling of vehicles in the system are presented in Algorithm 3 as shown in Figure 8. As seen in the algorithm, it is divided into six parts. In the first part, all the related variables are initiated as seen in the following Table 4.

TABLE 4. Variables used in Algorithm 3.

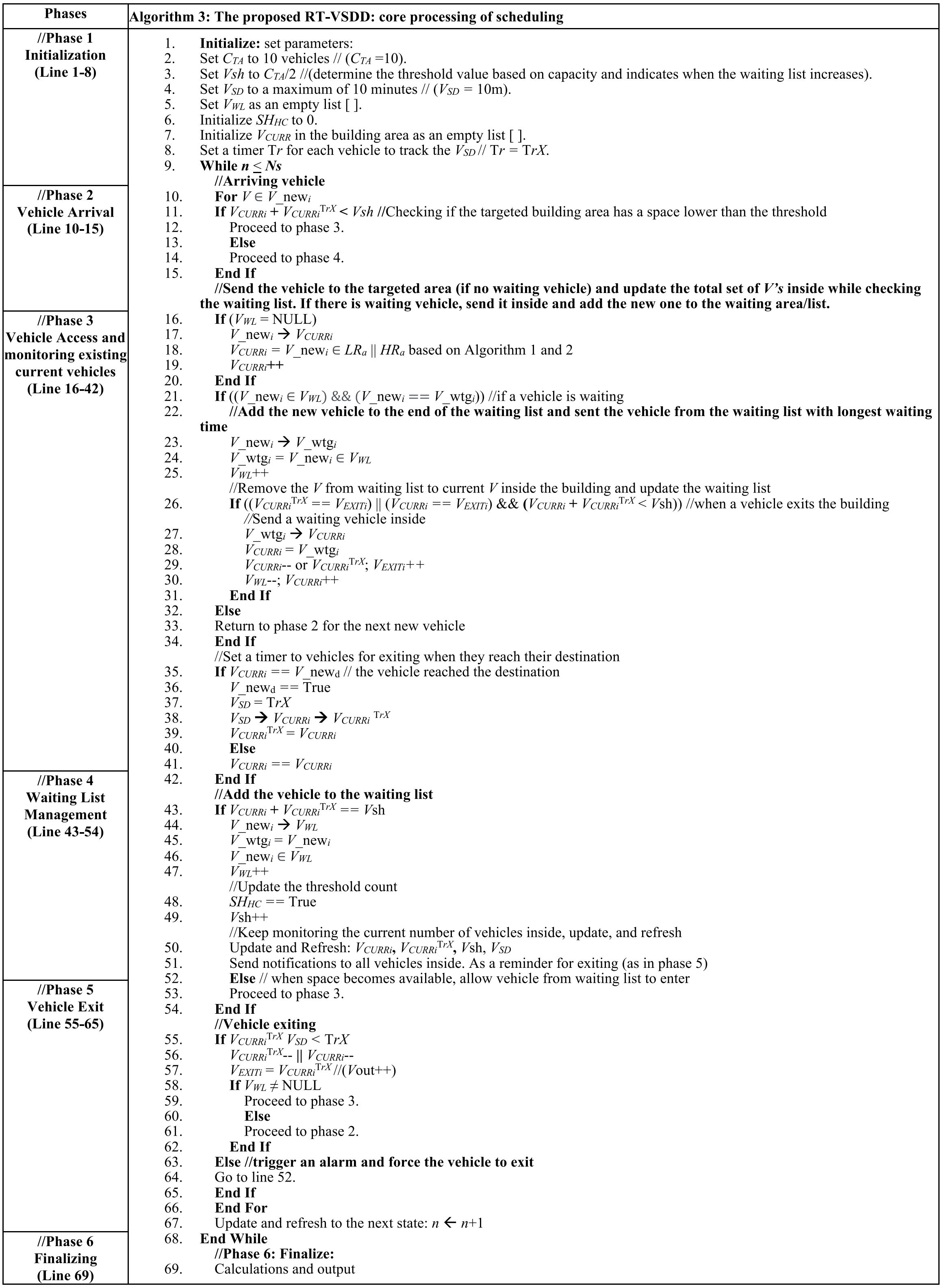
Term	Meaning
C_{TA}	The capacity of the targeted area
Vsh	Threshold of number of cars
V_{SD}	Stay duration of the vehicle
V_{WL}	Waiting list of vehicles
SH_{HC}	Threshold hit count
V_{CURR}	The current vehicles
V_{EXIT}	The exited vehicles

The related parameters are set in the first phase (steps 1-8) starting with the building area capacity C_{TA} which is used to set the threshold value of vehicle numbers which will be utilized as indicator for the waiting list increase whenever a new vehicle arrives which is already denoted earlier in Algorithm 1. The threshold value is set as half of the building capacity Vsh to $C_{TA}/2$ during a pandemic to limit and control vehicle density. The maximum time allowed per vehicle inside the area, which is denoted as the stay duration V_{SD}, the waiting list of vehicles waiting outside for their turn to enter their targeted area whenever a space is available is denoted as V_{WL}, the threshold hit count is denoted as SH_{HC}, and the current set of vehicles denoted as V_{CURR}, and when a vehicle exits the area, the V_{CURR} will become V_{EXIT}.

After setting the variables and parameters, the monitoring of arrival of vehicles is done in the second phase (steps 10-15) where a vehicle V arriving to the building V_new_i (line 10), the system checks whether the current set of vehicles in the targeted area are less than the threshold $V_{CURRi} + V_{CURRi}^{TrX} < Vsh$ (steps 11-15), where V_{CURRi}^{TrX} represents the current vehicles after reaching their destination inside the building. If true, the system proceeds to phase 3 (step 12) performing the vehicle access $V\_\mathrm{new}_i \rightarrow V_{CURR}$, otherwise, it will skip phase 3 and proceeds to phase 4 (step 14) and sends the vehicle to the waiting area, $V\_\mathrm{new}_i \rightarrow V\_wtg_i$, $V_{WL} + +$. The building capacity is more than the threshold which leaves an additional unoccupied space that can be used in case of emergencies or special cases.

In the third phase, (steps 16-42), vehicle access and monitoring the current vehicles inside the building V_{CURRi} are managed. The arriving vehicle is allowed access and sent to the targeted area (step 17) if there is no waiting vehicle and the waiting list is empty $V_{WL} = \mathrm{NULL}$ (steps 16-20), when the new vehicle $V_\mathrm{new}_i$goes inside, it will be identified as V_{CURRi}, and it will be a part of the vehicles inside the low-risk area or the high-risk area, LR_a or HR_a (step 18) based on the vehicle classification that is done by Algorithm 2, and the number of current vehicles is updated $V_{CURRi}{+}{+}$(step 19).

Besides that, there is another case of vehicle entry, specifically when the waiting list is not empty, where a waiting vehicle would be sent inside (steps 21-34) from the top of the waiting list V_{WL}(start-1), and the new vehicle V_new_i arriving will be sent to the end of the waiting area/list V_{WL}(end+1), and the numbers will be updated. When a vehicle V_{CURRi} arrives to its destination inside the



Phases — **Algorithm 3: The proposed RT-VSDD: core processing of scheduling**

//Phase 1 Initialization (Line 1-8)

```
1.  Initialize: set parameters:
2.  Set $C_{TA}$ to 10 vehicles // ($C_{TA}$ =10).
3.  Set $Vsh$ to $C_{TA}/2$ //(determine the threshold value based on capacity and indicates when the waiting list increases).
4.  Set $V_{SD}$ to a maximum of 10 minutes // ($V_{SD}$ = 10m).
5.  Set $V_{WL}$ as an empty list [ ].
6.  Initialize $SH_{HC}$ to 0.
7.  Initialize $V_{CURR}$ in the building area as an empty list [ ].
8.  Set a timer T$r$ for each vehicle to track the $V_{SD}$ // T$r$ = T$rX$.
9.  While $n \le Ns$
```

//Phase 2 Vehicle Arrival (Line 10-15)

```
        //Arriving vehicle
10.     For $V \in V\_new_i$
11.     If $V_{CURRi} + V_{CURRi}^{TrX} < Vsh$ //Checking if the targeted building area has a space lower than the threshold
12.         Proceed to phase 3.
13.     Else
14.         Proceed to phase 4.
15.     End If
```

//Phase 3 Vehicle Access and monitoring existing current vehicles (Line 16-42)

```
        //Send the vehicle to the targeted area (if no waiting vehicle) and update the total set of V's inside while checking the waiting list. If there is waiting vehicle, send it inside and add the new one to the waiting area/list.
16.     If ($V_{WL}$ = NULL)
17.         $V\_new_i \rightarrow V_{CURRi}$
18.         $V_{CURRi} = V\_new_i \in LR_a \,||\, HR_a$ based on Algorithm 1 and 2
19.         $V_{CURRi}$++
20.     End If
21.     If (($V\_new_i \in V_{WL}$) && ($V\_new_i == V\_wtg_i$)) //if a vehicle is waiting
22.         //Add the new vehicle to the end of the waiting list and sent the vehicle from the waiting list with longest waiting time
23.         $V\_new_i \rightarrow V\_wtg_i$
24.         $V\_wtg_i = V\_new_i \in V_{WL}$
25.         $V_{WL}$++
            //Remove the V from waiting list to current V inside the building and update the waiting list
26.         If (($V_{CURRi}^{TrX} == V_{EXITi}$) || ($V_{CURRi} == V_{EXITi}$) && ($V_{CURRi} + V_{CURRi}^{TrX} < V$sh)) //when a vehicle exits the building
                //Send a waiting vehicle inside
27.             $V\_wtg_i \rightarrow V_{CURRi}$
28.             $V_{CURRi} = V\_wtg_i$
29.             $V_{CURRi}$-- or $V_{CURRi}^{TrX}$; $V_{EXITi}$++
30.             $V_{WL}$--; $V_{CURRi}$++
31.         End If
32.     Else
33.     Return to phase 2 for the next new vehicle
34.     End If
        //Set a timer to vehicles for exiting when they reach their destination
35.     If $V_{CURRi} == V\_new_d$ // the vehicle reached the destination
36.         $V\_new_d$ == True
37.         $V_{SD}$ = T$rX$
38.         $V_{SD} \rightarrow V_{CURRi} \rightarrow V_{CURRi}^{TrX}$
39.         $V_{CURRi}^{TrX} = V_{CURRi}$
40.     Else
41.         $V_{CURRi} == V_{CURRi}$
42.     End If
```

//Phase 4 Waiting List Management (Line 43-54)

```
        //Add the vehicle to the waiting list
43.     If $V_{CURRi} + V_{CURRi}^{TrX} == V$sh
44.         $V\_new_i \rightarrow V_{WL}$
45.         $V\_wtg_i = V\_new_i$
46.         $V\_new_i \in V_{WL}$
47.         $V_{WL}$++
            //Update the threshold count
48.         $SH_{HC}$ == True
49.         $V$sh++
            //Keep monitoring the current number of vehicles inside, update, and refresh
50.         Update and Refresh: $V_{CURRi}$, $V_{CURRi}^{TrX}$, $V$sh, $V_{SD}$
51.         Send notifications to all vehicles inside. As a reminder for exiting (as in phase 5)
52.         Else // when space becomes available, allow vehicle from waiting list to enter
53.         Proceed to phase 3.
54.     End If
```

//Phase 5 Vehicle Exit (Line 55-65)

```
        //Vehicle exiting
55.     If $V_{CURRi}^{TrX}$ $V_{SD}$ < T$rX$
56.         $V_{CURRi}^{TrX}$-- || $V_{CURRi}$--
57.         $V_{EXITi} = V_{CURRi}^{TrX}$ //($V$out++)
58.         If $V_{WL} \neq$ NULL
59.             Proceed to phase 3.
60.             Else
61.             Proceed to phase 2.
62.         End If
63.     Else //trigger an alarm and force the vehicle to exit
64.     Go to line 52.
65.     End If
66.     End For
67.     Update and refresh to the next state: $n \leftarrow n$+1
68. End While
```

//Phase 6 Finalizing (Line 69)

```
        //Phase 6: Finalize:
69.     Calculations and output
```

FIGURE 8. The scheduling process in the proposed RT-VSDD: Algorithm 3.

building, it will be identified as V_new_{d}, and a timer TrX will be assigned and activated to the vehicle the equals to 10 minutes max for exiting the area and that vehicle will be identified as V_{CURRi}^{TrX}, otherwise the vehicle remains V_{CURRi} if roaming inside without reaching the destination (steps 35-42).

In the fourth phase, (steps 43-54), the system controls the waiting list and adds vehicles to the waiting area/list whenever the targeted area is full and the threshold is reached as stated in phase 2, line 14, when the condition $V_{CURRi}+ V_{CURRi}^{\mathrm{T}rX} > Vsh$(or $V_{CURRi}+ V_{CURRi}^{\mathrm{T}rX} == V\mathrm{sh}$, line 43) is met, where the system proceeds to phase 4. The vehicle will be added to the waiting area/list $V\_\mathrm{new}_i \rightarrow V_{WL}$, and the list is updated $V_{WL}{++}$.

The fifth phase is designed for vehicle exiting, (line 55-65). When the stay duration V_{SD} of the vehicle $V_{CURRi}^{\mathrm{T}rX}$ is less than the assigned timer TrX, the number of vehicles is decreased $V_{CURRi}^{\mathrm{T}rX}$–or V_{CURRi}–, as the final value of the V_{SD} of the vehicle is recorded once the vehicle exits where it will be identified as V_{EXITi}.

After the exit of any vehicle, the waiting list is checked where there will be two cases (lines 58-62), if it is empty, the system proceeds to the phase 2 and checks for arrival of new vehicles, otherwise the system proceeds to the phase 3 for monitoring with waiting vehicles management. On the other hand, when the timer of a vehicle has reached or exceeds the assigned timer, an alarm will be triggered and the vehicle will be forced to exit the area (line 63), and the system checks again for the lists when a space is available, going back to line 52, then proceeds to line 53 to proceed to phase 3 because the number of vehicle is supposed to be less than the allowed threshold at this point.

Before finalizing the process and making the final calculations and output as in phase 6 (line 69), the system updates and refresh the current state and continue to the next one $n \rightarrow n + 1$ (line 67), until all states Ns are completed (line 68).

IV. RESULTS AND DISCUSSION

In this section, all details of the proposed method along with the benchmark work are discussed. MATLAB software is used for implementing the algorithms. The MATLAB code includes the process for simulating vehicle data, running the algorithms, and then plotting the results.

The following Table 5 shows the transmission parameters of the LiFi and WiFi networks, vehicles, and COVID status rates of vehicles.

TABLE 5. Parameter settings.

Parameters	Value	Parameters	Value
Software	MATLAB	PD extent	3 cm^2
Radiation angle half-intensity	60	FoV semi-angle of the receiver	90
Number of vehicles	100	Optical filter gain	1.0
Quantity of WiFi AP	1	Refractive index	1.5
Quantity of LiFi AP	1	RF transmitter energy per AP	1 W
Area height	3.5	RF transmitter bandwidth per AP	20 MHz
Optical energy per LiFi AP	9 W	Optical to electric conversion efficiency	0.53 A/W
Modulation bandwidth of LiFi AP	40 MHz	Simulation time	100 min
Negative vehicles	75	Positive vehicles	20
No test vehicles	5	High and low temperature vehicles	30/70

Variables for algorithms are initialized, and to store data for plotting. The loop in algorithm 1 simulates the reception of new entry requests and exit requests. For each new entry request, the system simulates a test result (positive or negative) and a temperature check (high or low). In total, it is assumed there are 100 vehicles wherein some of them have positive test of COVID *TR*_ptv, and some of them consist of drivers with high temperature (positive and/or negative). All the data used for our method are shown in Figure 9 including *TR*_ptv, *TR*_ntv, no test, *LT*, *HT*.

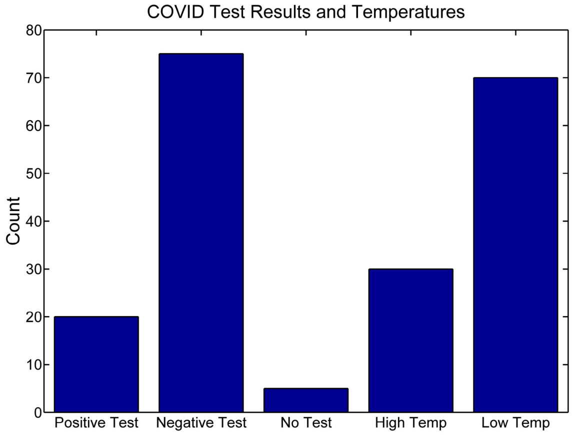


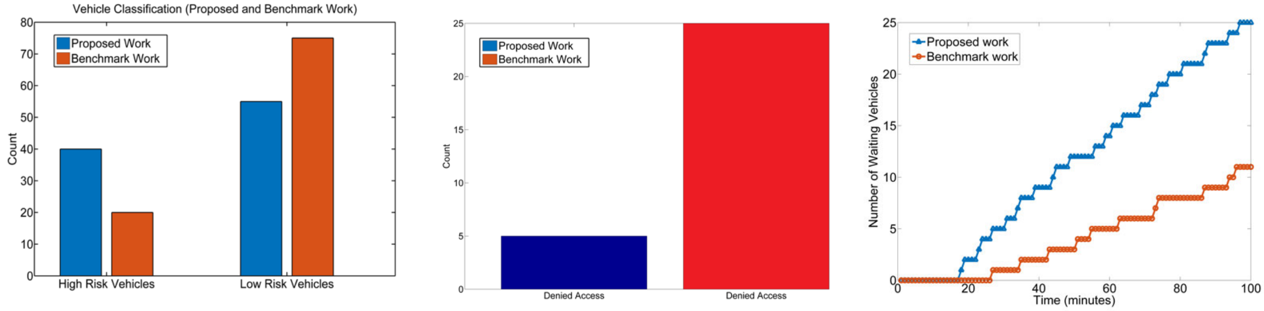
FIGURE 9. Statistics of vehicles and their health information including COVID test and body temperature.

In a real-world scenario, the vehicles approaching the building are identified and classified after reaching the building where their health data can vary based on multiple events and circumstances. However, all health data presented are fixed for fair comparison and to avoid randomness of the vehicle status where the focus is mainly about the technique itself including vehicles classification and building access control and limiting the number of vehicles inside the building efferently rather than controlling or changing the health status of the vehicles/drivers.

Note that the data presented in Figure 9 are used in the implementation for both, the presented work, and the benchmark work for fair comparison of performance. In addition to the data used for this work, other details can be used for vehicle classification. Health data can be changes by other techniques where applicable and suitable. For the proposed work, it is assumed there are some vehicles do not have a test results, which is set to 5 only. In addition, 20% of the vehicles are set to be positive vehicles, and 30% have a high temperature where the high temperature vehicles can be positive and negative as *shuffling the array* is used in the implementation code to ensure randomness of health status distribution for all vehicle is guaranteed.

As mentioned, depending on the test result TR and temperature *TR*_ptv/*TR*_ntv, *LT/HT*, the vehicle is classified and directed to the appropriate area. For each exit request, the system updates the vehicle counts accordingly. Output data is collected in arrays for plotting. All vehicles without a test result are to be denied access *V*den. In the Initialization, we initialize the total number of vehicles and randomly assign COVID test results and temperatures.

The counters for positive/negative tests and high/low temperatures are calculated. Vehicles are classified into



(a) Vehicle classification based on the health status, high risk and low risk.

(b) Vehicles denied access using the proposed work vs the benchmark work.

(c) Waiting vehicles rates.

FIGURE 10. **Simulation results including vehicle classification, denied access rates, waiting vehicles rates.**

high-risk and low-risk categories. Note that in the benchmark work [11], vehicles are classified as positive and negative only. Vehicle states (inside, outside, and waiting) are assigned for calculations.

When a vehicle is classified as high risk, it goes to the high-risk area if there is space, and the same is applied to the low-risk vehicles, as the maximum value (threshold value) for the building is set to 20/100, 10 for each area. However, in the benchmark work, there is only one area (the main building (MB)). All building space and threshold values are shown in Table 6.

TABLE 6. **Variables used.**

	Area classification	Threshold value
The proposed work	1- High risk area, and 2- Low risk area.	10 for each area (20 in total).
The benchmark work [11]	The main building (MB)	20

If the targeted area is full, the vehicle is classified as a waiting vehicle, and when a space is available in the targeted area due to the vehicles exiting their area, a waiting vehicle goes back and request an entry again.

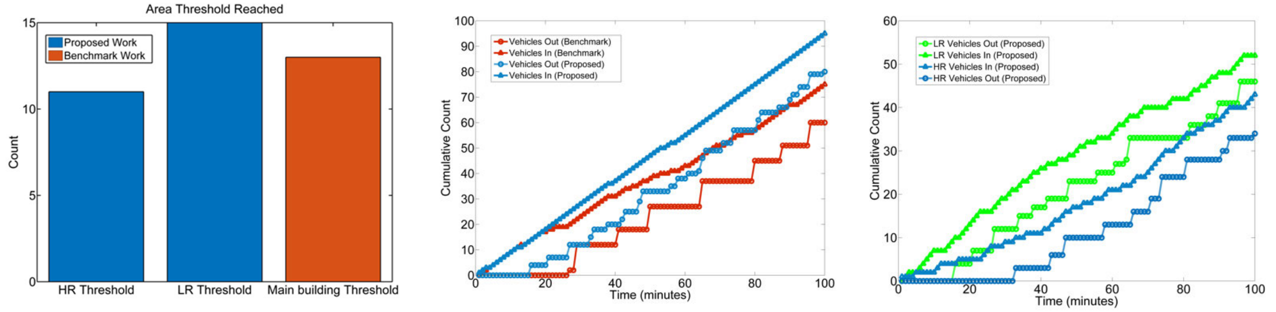
After the vehicle reaches the destination inside the building, a time is given to the vehicle through a notification to the vehicle, which is set to be 10 minutes max to exit the building. This is due the fact that each vehicle can spend a short or long time inside the area. A customized limited time per vehicle can be set after reaching the destination inside the building and configured in future designs similar to the proposed work. This can be set based on various factors including building size and the type of activity taking place. To simulate the arrival and departure of vehicles over time, we need to manage the states of vehicles dynamically as they arrive and depart. We'll use a time-based simulation where each minute, a new vehicle requests access. The proposed approach is structured and thorough, integrating both real-time simulation updates and visualization to monitor and analyze the flow of vehicles based on health risk criteria.

Figure 10 shows the simulation results by the proposed work compared with the benchmark work including rates of high and low risk vehicles, denied access rates, and rates of waiting vehicles.

As seen in Figure 10(a), the number of low-risk vehicles in the benchmark work is much higher than the proposed work, this is because the technique used in the benchmark work rely only on the COVID test only to classify users. This could result in allowing infected vehicles to enter the building without paying attention to symptoms such as body temperature.

When making decisions for vehicle entry, the main algorithm decides, based on specific criteria, to deny access for specific vehicles while allowing others to enter. One of the main differences between our work and the benchmark work is the number of vehicles that are denied access to the building due to their LR_V/HR_V risk status after obtaining the *new_health_check*. In Figure 10(b), the rate of denied access Vden vehicles is shown where only 5 vehicles were denied access by the proposed work, while 25 vehicles were denied access by the benchmark work. This is because the proposed technique blocks access of vehicles without a test $V\_\text{new}_i \notin \text{TR}$ where they are notified and asked to come back after making a test, while the benchmark work blocks access of all high-risk vehicles HR_V (TR_ptv only) having the positive health status TR_ptv without paying attention to other aspects. This feature makes the proposed work provide access to vehicles that are classified as TR_ptv/HT, which means processing more vehicle accessing the building.

All the vehicles that were denied access are not able to access or re-request access any time soon. On the other hand, one of the most important factors is marking vehicles as waiting vehicles where they must wait outside the building until a space is available in their targeted area, based on their classification. There is one factor that could influence this decision for the proposed work and the benchmark work as well, where vehicles can be marked as waiting vehicles V_wtg when the targeted area of the building (LR_a, HR_a, or MB) has reached its maximum capacity ($LR_a\_V\text{sh}$, $H_{Ra}\_V\text{sh}$, or $V\text{sh}$). The V_wtg is supposed to be set in a queue so that the first cars as processed first before allowing new one to proceed for an entry request. In Figure 10(c), the waiting rates of vehicles are shown where



(a) Vsh value in each area of the building including HR, LR, and MB.

(b) Total number of vehicles entered and exited the building using the proposed work vs the benchmark work.

(c) Total number of vehicles entered and exited the HRa and the LR_a using the proposed work.

FIGURE 11. **Vehicle Simulation results including number of vehicles entered and exited the areas of the building and the *V*sh values.**

25 vehicles in total were set as V_wtg at the end of the simulation out of 100 by the proposed work, while only 11 vehicles were marked as V_wtg by the benchmark work. This increase is more than 50% by the proposed technique shows higher entry control of vehicles. Note that at the end all waiting vehicles must be processed and their entry request must be complete because every vehicle inside its area will exit the building after spending some time. despite the long waiting times, the proposed technique controls vehicles entering the building which means less infection rates.

After processing the entry request and classifying the vehicles, as vehicles are marked as waiting as seen in Figure 10(c).

The threshold value Vsh aims to control the number of vehicles inside each area of the building to ensure distance is obtained and crowded situation is avoided. The Vsh value is fixed in each area based on the building size. Every time each area reaches the maximum allowed number of vehicles, a Vsh is reached.

Figure 11 shows the simulation results by the proposed work compared with the benchmark work including Vsh in each area, total number of vehicles entered and exited, and total in and out of areas using the proposed work.

Figure 11(a) shows how many times the Vsh reached in each area where blue bars are linked to the proposed work, and the red bar is linked to the benchmark work results. In the HR area, the Vsh value hits 11 times only and in the LR area the Vsh value hits 15 times (26 in total) while 13 times was achieved by the benchmark work for the MB area. This is because the proposed technique aims to divide the building into two areas for higher control levels.

All the results in Figure 10(c) and 11(a) that were achieved by the proposed work are higher than the benchmark work because more vehicles are accessing the building which makes the Vsh value reached faster using the proposed work which leads to higher number of vehicles marked as V_wtg.

After classifying and vehicle entry control process, it is important to calculate the total number of vehicles that entered and exited the building. In Figure 11(b), the total number vehicles entered Vi the building has reached 95/100 using the proposed technique and that is 95% of all vehicles, while only 75 were able to access the building using the benchmark technique. This rate is the opposite number of denied vehicle as seen in Figure 10(b). On the other hand, in Figure 11(c), the number of vehicles entered and exited the high-risk area HRa_Vin and HRa_Vout, and the low-risk area LRa_Vin and LRa_Vout using the proposed work is shown where the $LRa$was able to contain more vehicles due to the rates of infections based on the classification of vehicles.

The proposed technique outperforms the benchmark technique by controlling and limiting the number of vehicles inside the building more effectively through the proper detection and vehicle classifications and monitoring. Therefore, the infection rates are expected to be minimized. In addition to lowering the infection rates, when using the proposed RT-VSDD, the negative impact on the economical side is expected to be minimized where the building is able to accommodate higher number of vehicles, process, and allow access to all vehicles including LR_V and HR_V.

V. FUTURE WORK

In the future works, a full analysis for the negative economic impact is expected that can provide insights on the real benefit of the proposed system on the economy locally and globally. Furthermore, optimizing the proposed model and its related data workflow is subject to future work. Further research and adoption of actual vehicletraffic datasets should be conducted to evaluate the system's effectiveness. In addition, the presented work was specifically designed for COVID-19 situation including type of tests, components like sensors which are related to the symptoms of the disease. The presented system can be improved by considering alternative solutions and components to be suitable for other diseases which means using other types of tests and measurements.

The system design described can be developed for the capability to establish connections with multiple smart buildings and with other test centers and effectively handle various sorts of tests and measurements. Nevertheless, this task will pose a challenge since it has the potential to augment the intricacy of the system, resulting in longer waiting periods. Thus, it is feasible to customize the system to particularly detect and monitor the tests and symptoms associated with the ongoing pandemic, utilizing specialized criteria, measurements, and sensors.

The event of crashing of some entities can be considered in the future works where the algorithm may consider the loss of some data or the disability of some functions for example the disconnection of the server might cause loss/inaccurate COVID test results which means an alternative path of action must take place to precent system crash, or in case of network failure.

VI. CONCLUSION

The developed system in this paper categorises vehicles according to their health status and directs them to designated areas based on their classification. It utilises data from COVID-19 test centres via a cloud-based computing system. This study developed the notion of low-risk and high-risk areas within the building and introduced the idea of task processing for infected users. The system also regulates the queue of vehicles and synchronise all components using the intelligent building management system, mobile application, and notifications distributed to all stakeholders. Three algorithms were presented, with the first algorithm responsible for controlling all functionalities, the second algorithm specifically focuses on classifying vehicles, while the third algorithm shows the full process of vehicle classification throughout the system. The performance evaluation was conducted by means of simulations using the MATLAB software. 100 vehicles were assumed in the presented scenario with 5% untested, 20% positive, 75% negative, 30% high temperature, and 70% low temperature. Only 5% of vehicles were denied access using the proposed system and 25% by the benchmark work. The total waiting vehicles rate was 25% and 11% in favour of the proposed work for a total waiting time of 100 minutes.

The results reported in this study demonstrate the advantages of the proposed system in managing and restricting vehicle access to the smart building. The system effectively reduces the negative consequences by managing vehicles and their waiting times and minimizing the number of denied vehicles.

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