Telematics and Informatics Reports 17 (2025) 100178

Contents lists available at ScienceDirect

Telematics and Informatics Reports

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

Empowering Pandemic Resilience: Simulation of Integrating IoT Innovation to Curtail Mortality

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ARTICLE INFO

Keywords:
PEP-Pandemic and Epidemic Prone Disease
Wearable Strain Sensor
COVID-19
Internet of Things
WBAN
Respiratory Sensor, Cisco Packet Tracer

ABSTRACT

Historically Pandemic and Epidemic Prone (PEP) diseases rapidly inflame the respiratory tract and influence heart rate very badly, like how corona virus 2019 was transmitted by SARS-CoV-2. Thus, this article proposes a conceptual design that considers heart rate change, and respiration rate variations measured are indicated through IoT with a mobile application. Here the app-based method solves the connectivity gap through technology infusion, which was needed during pandemic. Since wearable devices to measure heart rate/ respiratory rate are commonly available, here the proposal suggests one such best-suited wearable strain sensor to focus on respiration rate and volume of a human respiratory system with high fidelity for servicing PEP patients. The proposed concept can help in monitoring and tracking multiple patients simultaneously, online through Internet of Things (IoT). This IoT enabled app not only updates doctors on already discharged patients, but also can be used by anyone to prevent last minute uncertainties. Since respiratory issues being one of the main symptoms of patients recovered from PEP disease, tracking the breathing patterns is essential. This issue requires an effective sensorics system and associated software applications, thus connecting hospital administration to the public. The aim is to help the public use a single software application to access the ambulance, hospital, and doctors, reducing time via data transfer leveraging IoT. This has been simulated using Cisco packet tracer for fast processing of data and the results are observed. As a pre-requisite of the application respiratory rate data set has been converted and the required alert indications have been shown after comparing with reference data set.

1. Introduction

A corona is a type of infectious virus that very quickly causes the infection of the nose, sinus, or upper throat of any human body. The lungs tend to be the most frequently involved organ in coronavirus disease, with a spectrum in extreme viral effects by coronavirus [1]. Pneumonia complications in coronary artery impaired elderly people can appear to impact severely on each lung in Pandemic and Epidemic Prone Disease (PEP), where inflammation usually contributes to liquid loading of tiny air packs in the respiratory system affecting lungs [2]. Breathing rate, often regarded as respiratory frequency (fr), and tidal volume have been described as behavioral and metabolic elements of minute ventilation, all between [3]. Various methodologies for calculation of fr, complicating the selection of the sensor [4], must be taken into consideration [5]. Prolonged breathing control procedures in several hospitals include respiratory inductive or optoelectronic plethysmography [6]. According to the author R. Farre, the airflow variations of patient were often evaluated by collecting impulses in flow or volume via pneumotachographs, thermistors or thermocouples, thoracic abdominal lines, or nasal prongs [7]. A viral respiratory infection occurs if the cells of respiratory mucosa[8] membranes are infected by a virus, that could be because of inhalation of the molecules of various types of viruses or if it directly penetrates the nose or eye amniotic fluid surface etc [1],[9]. SARS-CoV-2 enters airway cells through the

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https://doi.org/10.1016/j.teler.2024.100178
Received 27 July 2024; Received in revised form 21 September 2024; Accepted 24 November 2024
Available online 30 November 2024
2772-5030/

Angiotensin-Converting Enzyme 2 (ACE2) receptor, a molecule that connects our cells' interior to the outside through the cell membrane. As a result, few people respond to the virus's influence by activating their powerful immune system, resulting in a so-called cytokine storm with rapid blood clotting, which can all lead to lung cell injury [6]. The body substitutes thick and rigid cells destroyed by the virus with scar tissue. This may lead to a disorder known in people with PEP [10], called 'pulmonary fibrosis,' and it significantly affects the lungs by making people breathless [11]. Corona viruses have also shown a strong systemic inflammatory reaction [12] and localized vascular inflammation [13]. It raises the risk of thromboembolic and myocarditis in the acute phase of infection. Three subgroups will separate potential long-term health issues: cardiorespiratory, gluco-metabolic, and neuropsychiatric issues [14].

Generally, the count of breaths a person takes every minute is considered as the respiration rate or breath per minute (bpm). For an adult during rest, 12 to 20 breaths a minute are the usual breath rate. A breathing rate less than 12 or more than 25 breaths is regarded irregular while relaxing [15]. Breathing volume is the tidal volume of lungs that reflects the usual amount of air transferred during inhalation and exhalation without any extra force. In young adults, the tidal volume is around 7 mL/kg of body mass or nearly 500 mL per inspiration [16]. Here we recommend a set of 2 accurate and reliable, wearable strain sensors equipped to measure the variations of breathing rate and the volume of corona affected patient's during PEP. By considering the standard deviation of Body mass index (BMI) [17] of normal human as reference of respiratory system, the alterations in the sensed data of breathing rate and volume from two sensors connected perpendicular to each other and the collected data could be calculated very well through comparison basis. This sensor allows us to track the data of multiple patients' respiratory system parallelly via Internet of Medical things (IoMT) online. Also, there are few death cases that happened during PEP because of breathlessness even after the patient is deemed to be negative (post covid patients) and is released from the hospital. This suggested sensor system could be used by the patients easily as a lifesaving system even after discharge from the hospital as it is portable.

During PEP, an effective sensing system with software applications connecting hospital administration to the public has become an urgent requirement. The proposed conceptual design will be useful in conveying information about the need to the nearest ambulance through the software due to its alarm. The patient will be safely delivered to the concerned hospital with the provision of necessary oxygen supply via ambulance. As a result, getting to the hospital or the concerned doctor will be easy, time-efficient and lifesaving.

2. PEP impacts on lungs

During normal state of human body, the rate of breaths per minute (bpm) usually varies between 12 - 20 bpm. List of respiratory rates of normal human body depending on their ages are as in Table 1 below. Generally, respiration cycle occurs in 2 stages. i.e inhalation/exhalation. while inhalation, oxygen enters the lungs and is carried throughout the body through the bloodstream, but while exhalation, carbon dioxide is expelled out of the body through nose [18].

Table 1
Average resting respiratory rates by age [19,20].

Humans	Age range	Respiratory Rate (RR) Breaths Per minute
Infants	Birth – 6 weeks	30–50 bpm
	6 months	25–40 bpm
	3 years	20–30 bpm
Kids	6 years	18–25 bpm
	10 years	17–23 bpm
Adolescent	12-18 years	15–22 bpm
Adults	25 years above	12–18 bpm
Elderly	≥ 65 years	12–28 bpm
	≥ 80 years	10– 30bpm

Fig. 1 depicts an example of the various stages that a PEP affected patient goes through on a date-by-date basis [21], wherein breathlessness is also one of the stages that can be fatal in severe conditions. The discovery of an active chronic infection in the upper respiratory system has consequences for the PEP restraint [22].

3. Cases and death rates during/post corona (virus disease) 2019

According to the data during the year 2020 available at World Health Organization board regarding overall PEP positive. below listed data comparisons are from WHO Coronavirus Disease /PEP Dashboard as per the Data last updated: 2020/12/20 and, 5:14pm CEST [23,24]. The regularities of symptoms between different infections, as shown in Fig. 2, highlight the need for accurate monitoring of respiratory changes in patients [25]. However, during the second phase of covid death counts were high in April 2021 and are now decreasing in June 2021. From WHO data we could compute the death rate percentage for 2020 and 2021, as shown in Figs. 3 and 4, respectively.

The PEP-Associated Hospitalization Surveillance Network monitors laboratory-confirmed PEP-associated hospitalizations in select counties participating in the Emerging Infections Program (EIP) and states participating in the Influenza Hospitalization Surveillance Project (IHSP). As per PEP Laboratory-confirmed data [26], among 7,865 sampled patients hospitalized during March 1–May 31, 2020, where 90.9% of cases reported at least one underlying medical condition as shown in Fig. 5. Most common cases reported because of corona virus were 10.8-12.7% asthmatic and 19.4-20.9 % chronic lung disease. Here both asthmatic and lung disease are under respiratory system [28]. From the latest scenario the variants of corona like delta and delta plus could affect the recovered patients and probability of spreading infection will be higher [29,30]. Delta plus has a stronger reactivity for the mucosal lining of the lungs than other variants, but it is unclear whether this causes damage or not. It does not also mean that this variant is more serious or transmissible [31]. The ratios of probabilities of symptoms sustainability in post PEP patients can be seen in Fig. 6. After 90 days of recovery, the presence of 1.8 percent of breathlessness symptoms, as shown in Fig. 7, is a strong indication of a life-threatening condition, emphasizing the importance of seeking a suitable device that identifies the seriousness of breathing rate variations [32]. As documented, many patients continue to suffer long-term symptoms post-COVID-19, including breathlessness and fatigue, indicating a prolonged recovery period [33].

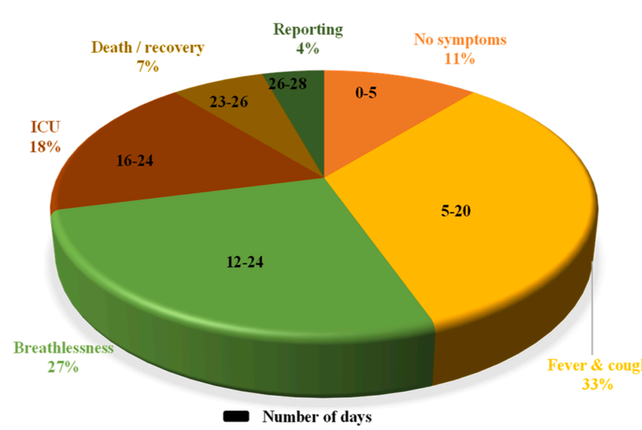

Fig. 1. Various stages that a PEP affected patient goes through over time [21].

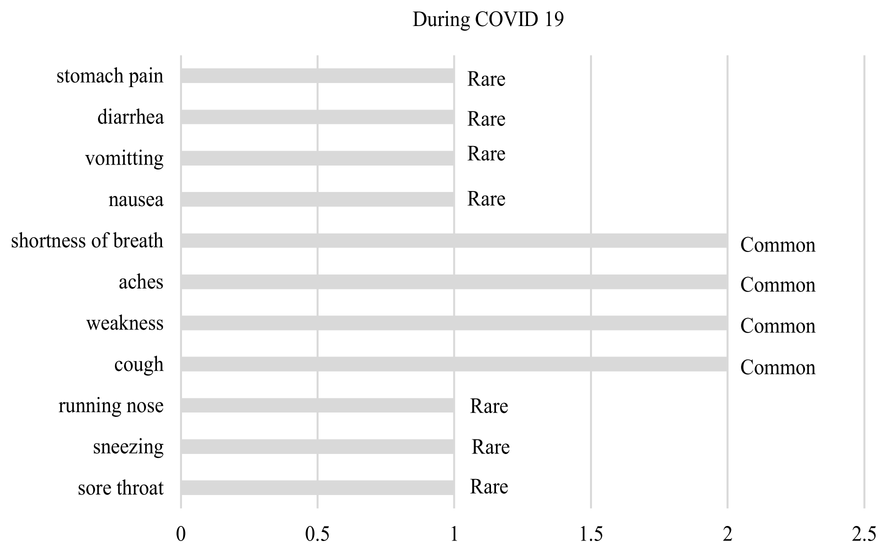

Fig. 2. Regularities of symptoms comparison with different infections [25].

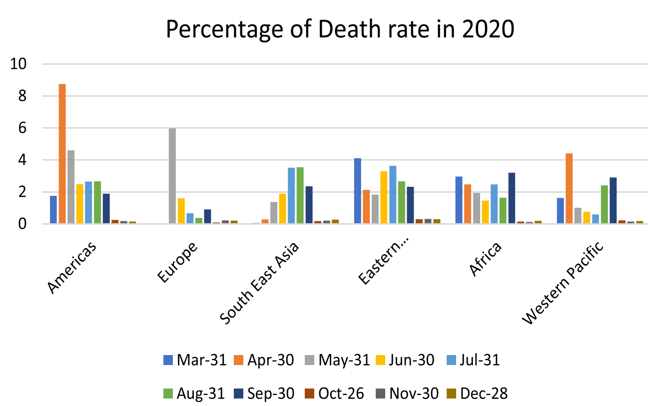

Fig. 3. Detailed percentage calculation and mapping during 2020 with respect to different countries from WHO.

4. Methodology

Under normal daily environments, most available respiratory testing devices cannot monitor a patient's breathing under daily routine conditions. But with IoMT, it is easier to keep an ongoing track of up-to -date readings/data with the proposed strain sensor. Spirometry is an example of pulmonary function tests (PFTs) which require the patient to breathe through a mouthpiece, which is a difficult maneuver to master and does not adapt to long-term use. Hence PFTs are not suitable. The conceptual design process is as shown in Fig. 8 below which is self-explanatory. Where HR- Heart rate, RR-respiration rate. Depending on the attached wearable sensor readings with respect to HR or RR, beyond the provided ranges, through the mobile application automatic alarm and messages will be sent to ambulance, concerned doctor and hospital as detailed in Fig. 8. The alarm indication received by the nearest ambulance will try to approach the patient address by tracking signal.

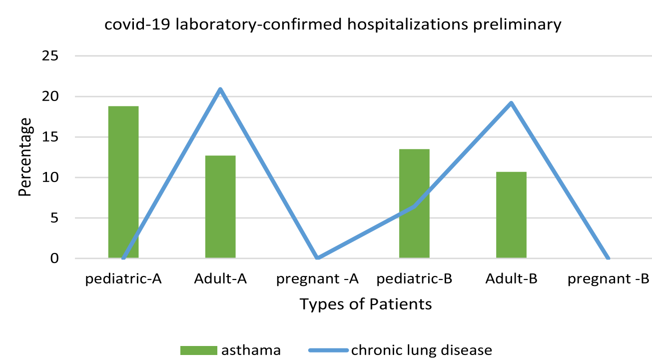

Fig. 5. Coronavirus affected positive cases according to PEP laboratory-confirmed hospitalizations preliminary. data (A) as of April 25, 2020 [26,27] [28] and data (B) as of Dec 12, 2020 [28].

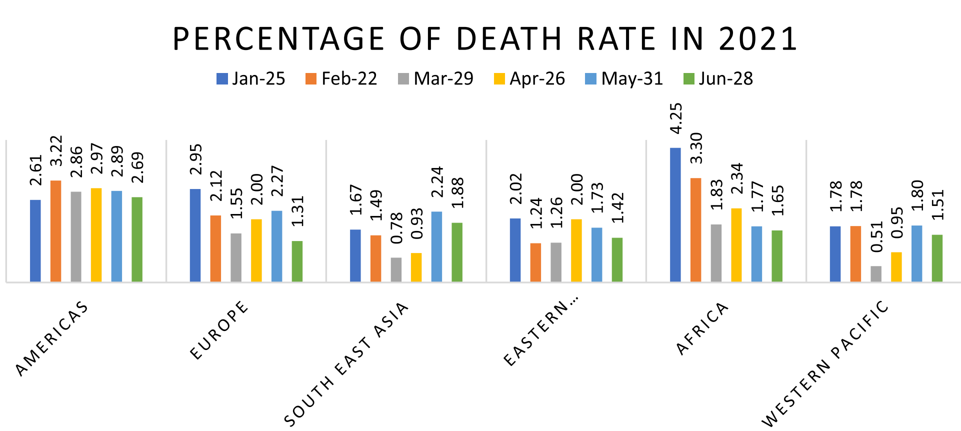

Fig. 4. Detailed percentage calculation and mapping during 2021with respect to different countries from WHO.

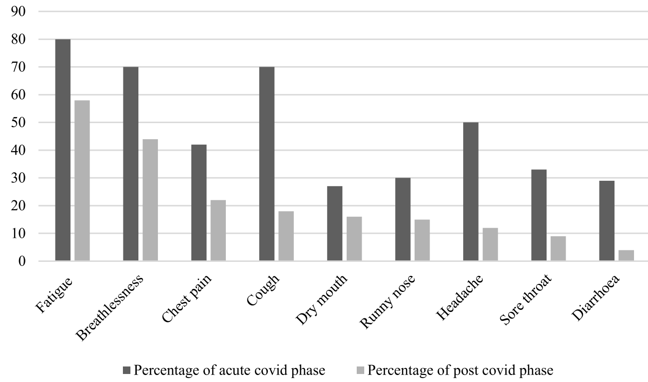

Fig. 6. Post PEP persistent symptoms [65].

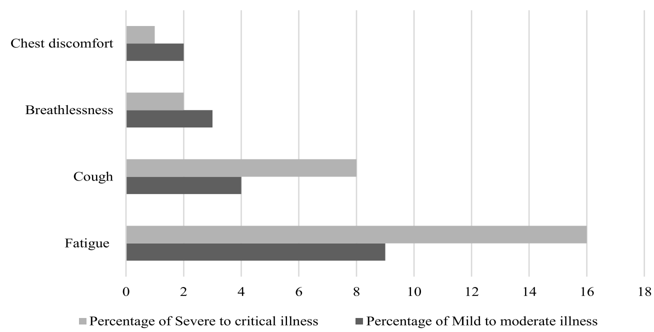

Fig. 7. The prevalence of various symptoms for 90 days after recovery from acute PEP in older adults.

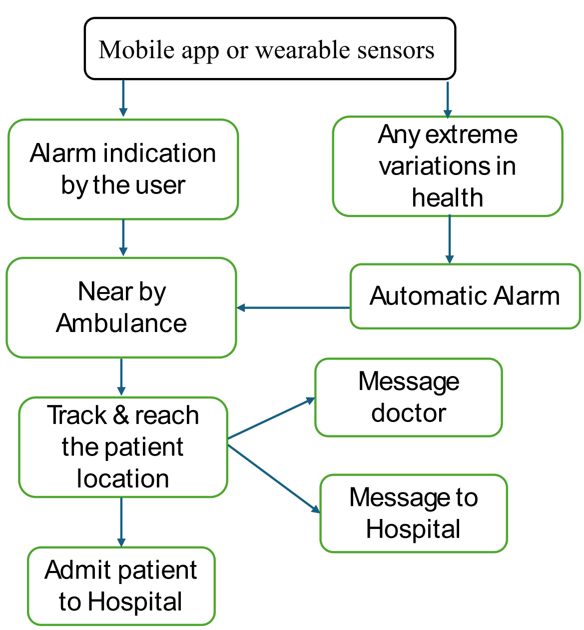

Fig. 8. Conceptual Design Process.

Also ambulances will try to communicate to nearest hospital. As the nearest hospital receives an emergency message from ambulance, it will provide confirmation depending on the availability of the beds at hospital. Details of ambulance and nearest hospital acceptance will be communicated to registered doctor through App message, where the doctor can take decision of reaching the patient by going to that hospital or if not possible, doctor can transfer the patient health history to the recent confirmed hospital. So that the new doctor at hospital can go through it within the patient reach to hospital and take better decision about medications or treatment required for saving patient life. This proposed concept works well only if there is coordination from the government and private hospitals and ambulance as the patient's life is prioritized.

For RR readings we have concentrated on the derived method below, i.e., illustrated in Fig. 9, the connection arrangement is easily observed by attaching two strain sensors perpendicular to each other to a human body's ribcage and abdomen. Respiratory surveillance bands, fiber Mach-Zehnder interferometer (FMF-MZI) are volatile and slippable, these techniques do not allow patients to be monitored in their homeland throughout the day during their walking mode. But it would be even easier to recognize the respiration of a moving and running human body in the case of proposed piezo-strain sensors. Formulation of the wearable RF sensor with increased ambient gesture tolerance near the transmitter and receiver that makes Near-field Coherent Sensing rarely getting affected because of environmental Modifications in relation to direct reflectance of far-fields. The movement of the antenna will cause significant radiation effect because of Interference within it. The requirement of efficient data analysis and processing equipment was challenging to rectify the unwanted signals. By measuring the variations of pressure distribution at the ribcage and stomach during the air in taking and out letting process the wearable strain sensor can easily detect changes in metabolism (the chemical reactions that occur within the cells of the body that convert food to energy), respiratory rate and intensity, breathing volume [6]. The key benefit of it is - simple and easy portability, a reduced power expenditure, and can also be controlled through a wireless Bluetooth device. Also, PEP sufferers with mild admittance syndromes worsen, with a death rate of 14%.

4.1. *Wearable strain sensors*

The strain sensor involves a piezo resistive material slender film stored in a silicone elastomer surface. This technology has been used through the controlled deterioration of the metal film to enhance stress across the resistance ratio. The nano and micro arrangement is integrated to form wrinkle film that functions mostly as stress reduction aspects and helps to monitor crack propagation in such a way that it can offer a better dynamic range thus maintaining sensitivity as shown in Fig. 9. It is true that the breathing sensor has a smaller footprint than a popular band-aid support and only tracks local adjustments to the corresponding torso positions.

If individuals with chronic issues are at elevated risk during PEP, e.g., for diabetes, respiratory problems, or heart diseases, must take special care by taking proper medications suggested by their physicians. Along with this for aged people continuous tracking of breathing data through measuring devices is a must, when they are hospitalized because of coronavirus effect. At this situation, the easy and simpler way of breathing rate and volume test with centralized IoMT connection will be very helpful for doctors and patient's coordination and time saving. As shown in Fig. 9 the strain sensors could be applied on the ribcage and abdomen to measure the expansion and contraction of the respective locations during respiration. The sensors can still record respiration signals under walking and running conditions. The sensors have small footprints, with a dimension of 21mm by 10mm by 5mm and it must be placed perpendicular to each other to minimize crosstalk. Double-sided, adhesive has to be used to adhere the sensors to the skin and avoid slippage [6]. Maintaining the track of Respiration during Motion is an important and challenging aspect here.

The strain sensors and accelerometer alignment must be maintained in accordance with subjects/the human body to simultaneously assess volume. The strain sensors must be able to measure the variations of respiration even during the displacement of the rib cage and the abdomen while doing any physical activities. Patients with increased respiratory frequency (RR $\geq$ 30 bpm) and decreased oxygen index (partial oxygen pressure/inspired oxygen proportion up $\leq$ 200 mmHg)

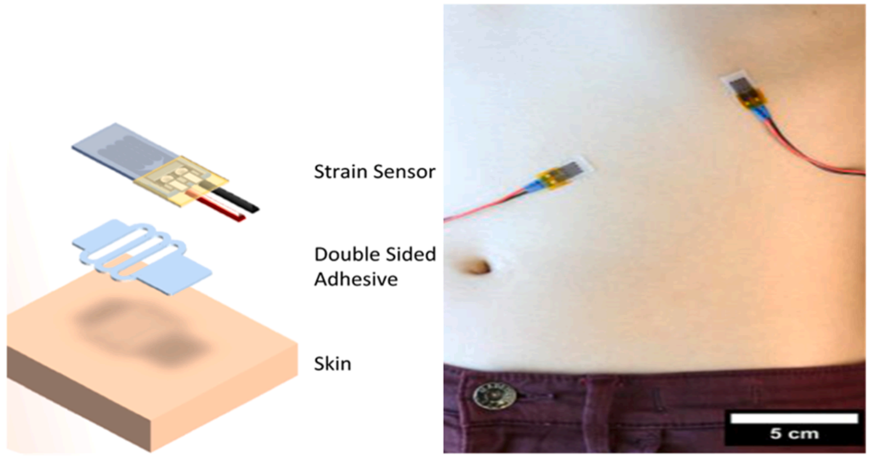

Fig. 9. The strain sensor and double-sided tape in order of attachment on the skin [6].

must also be identified as crucial cases for heavy-flow oxygen treatment in nasal cannula. The higher frequency movement artifacts can be extracted from the stress sensor data using a low pass filter. The breathing movement should be proportionate in both regions of the nose to the amount of inhaled and exhaled air for healthy people, and it is possible to measure breath amount by considering the correlation matrix of the changes in the respective locations.

Note: As ensuring the survival of patients' lives is our foremost priority, certain innovative ideas are required, such as:

- The requirement that all ambulances operate in a centralized manner, regardless of their brand or company. enabling any nearby ambulance (regardless of brand or company) to rapidly reach the patient and communicate with the nearest hospital.
- An application-registered physician would need to have the ability to approach a patient in need at any establishment of hospital to which they have been referred by the ambulance. i.e Doctors must have the liberty to treat their patients anywhere, regardless of the hospital. If a registered doctor couldn't reach the patient on time due to various reasons, at least he should be able to provide access to patient history information for attending physicians at ambulance-assisted hospitals.
- Doctors are granted access to patient medical histories for 24hrs through the proposed application. So that, any doctor of the-ambulance *approached* hospital will be able to access medical history of the patient to take proper and quick decision to save the patient. Also, as a patient data privacy policy is concern, only the registered personal doctor of the patient can provide access of patient data history records to concerned hospital doctor.

The aforementioned factors are essential, as every second counts towards maintaining the patient's life.

5. Acquiring data with signal conversions

A wearable strain sensor is fitted around the ribcage and the abdomen, for measuring the respiration rate through its deformation. The film attached here would deform due to the ribcage and abdominal movement variations, causing the electrical resistance to vary at internal coil of strain sensor. This variation in resistance, measured ideally with a Wheatstone bridge, is correlated with the strain by the volume known as the measurement or gauge factor. The data acquisition procedure is a sampling process that measures health problems in the actual world and converts acquired signals into numerical digital bits that can be modified by a laptop. However, in their results, there is little change at the end-exhalation, merely a linear rise in the breathing flow rate caused by an athlete's motion or effort. The contents and information of mobile apps that need to be available to a variety of end users is depicted in Fig. 10. The options of messages shown to the patient from the ambulance are highlighted in yellow. Also, the messages shown to the ambulance from the mobile app are highlighted. Similarly doctors message with hospital confirmation is also sent by the app for mutual communication and confirmation as in Fig. 10 where figure itself is self-explanatory.

5.1. MATLAB simulations

We were able to convert the raw respiratory analog signal sample [34] [35] into respiratory rate per minute using signal sampling theorem and Fourier transforms [36] through MATLAB software. By varying the sampling rate in MATLAB simulations like 10, 25, 41 samples per second etc., we were able to obtain various breathing rates of a normal person as shown in Fig. 11. We implemented an FFT programmed in MATLAB to obtain respiratory rate by collecting a dataset of a normal person's respiratory signal from BIDMC data set [34,35] and used it as a reference input signal for the simulation program testing purpose. Fig. 11 shows that the respiratory rate obtained per minute (60 seconds) is 9 bpm and 37 bpm respectively, with peaks of signal indicated by an arrow. Also, through MATLAB by providing the cutoff ranges we could be able to differentiate the slow, medium and fast RR as in Fig. 12, with indications of alarm depending on the received signal.

5.2. CISCO packet tracer

To establish effective communication between a patient's phone and the hospital, including other intermediaries like the nearest doctor and

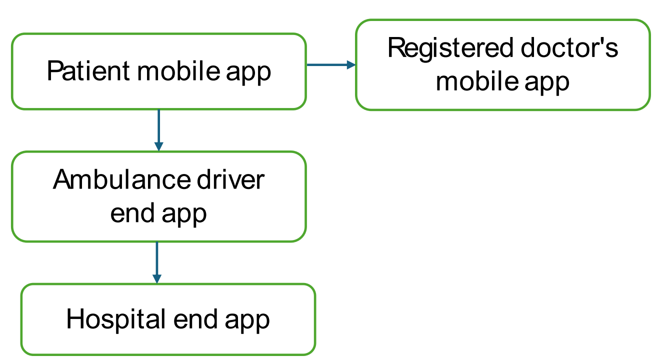

Fig. 10. Mobile app information transmission that must be accessible for different end-users.

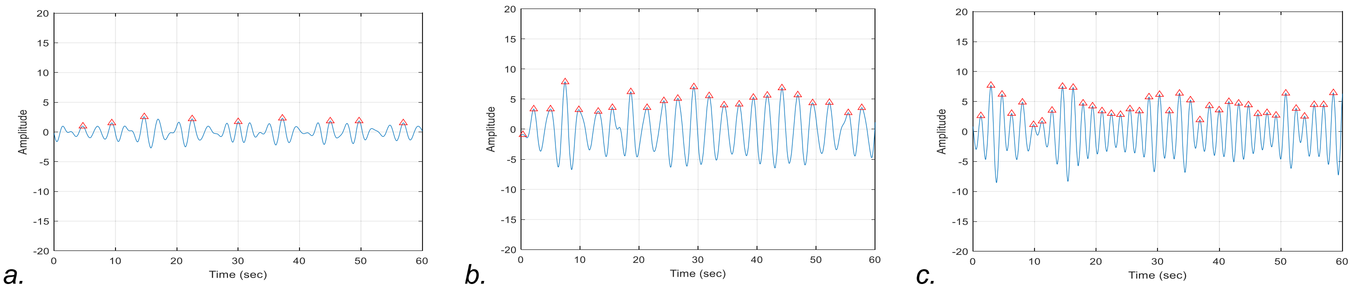

Fig. 11. a). Slow, b). Medium and c). Fast, breathing rates obtained through MATLAB simulations.

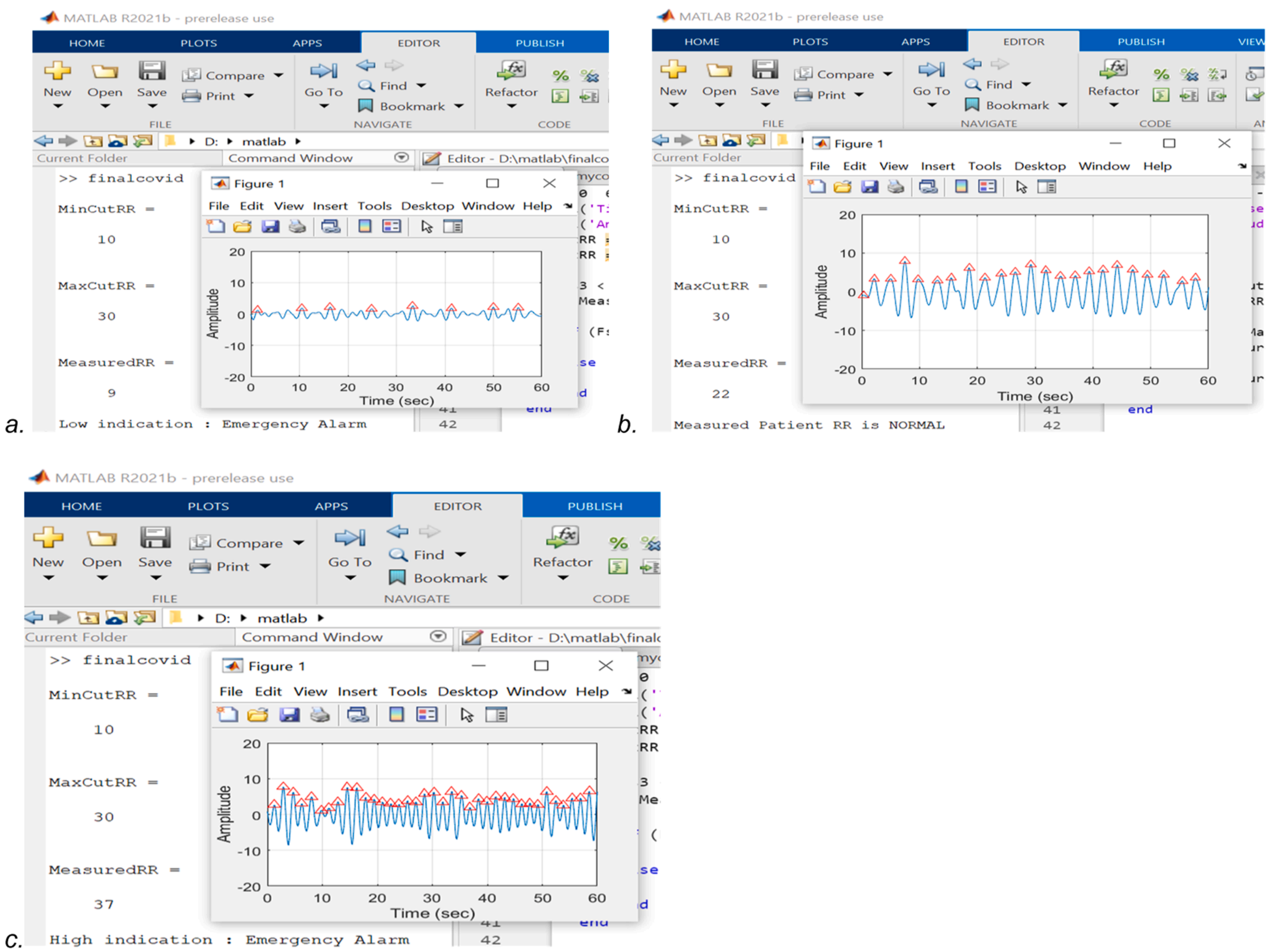

Fig. 12. a) Slow, b) medium and c) fast breathing rates verified through MATLAB simulations for alarm indications.

ambulance services, a well-defined communication model is essential. One approach to testing and validating this model is by utilizing Cisco Packet Tracer (CPT), a simulation software designed for creating complex network topologies and simulating various networking concepts.

CPT serves as a virtual environment that closely resembles real-world computer networks, providing a playground for users to explore and experiment with different networking scenarios. By using CPT, one can validate the proof of concept for the communication system, ensuring that it functions as intended and meets the requirements for seamless communication between the patient's phone, hospital, doctors, and ambulance services. Fig. 13 depicts the simulated real-life scenario, which has incorporated the possibility of multiple patients requiring emergency attention. To ensure efficient communication and coordination, various entities have been interconnected, including patients, ambulances, doctors, and hospitals, through different communication interfaces. Fig. 14 depicts Each patient's sensors are linked to their smartphones using Bluetooth or wireless communication. The smartphone app continuously monitors the patient's readings and triggers an alert if the readings deviate from the normal range. The trigger promptly sends messages to the nearest doctor from a registered database and to the nearest ambulance using GPS. Where the primary focus is to ensure that patients receive necessary care even before reaching the hospital.

Patients' smartphones establish connections with doctors, ambulances, and hospitals through 3G/4G cellular interfaces provided by carriers like Airtel, Jio, Vodafone, etc. When an emergency call is

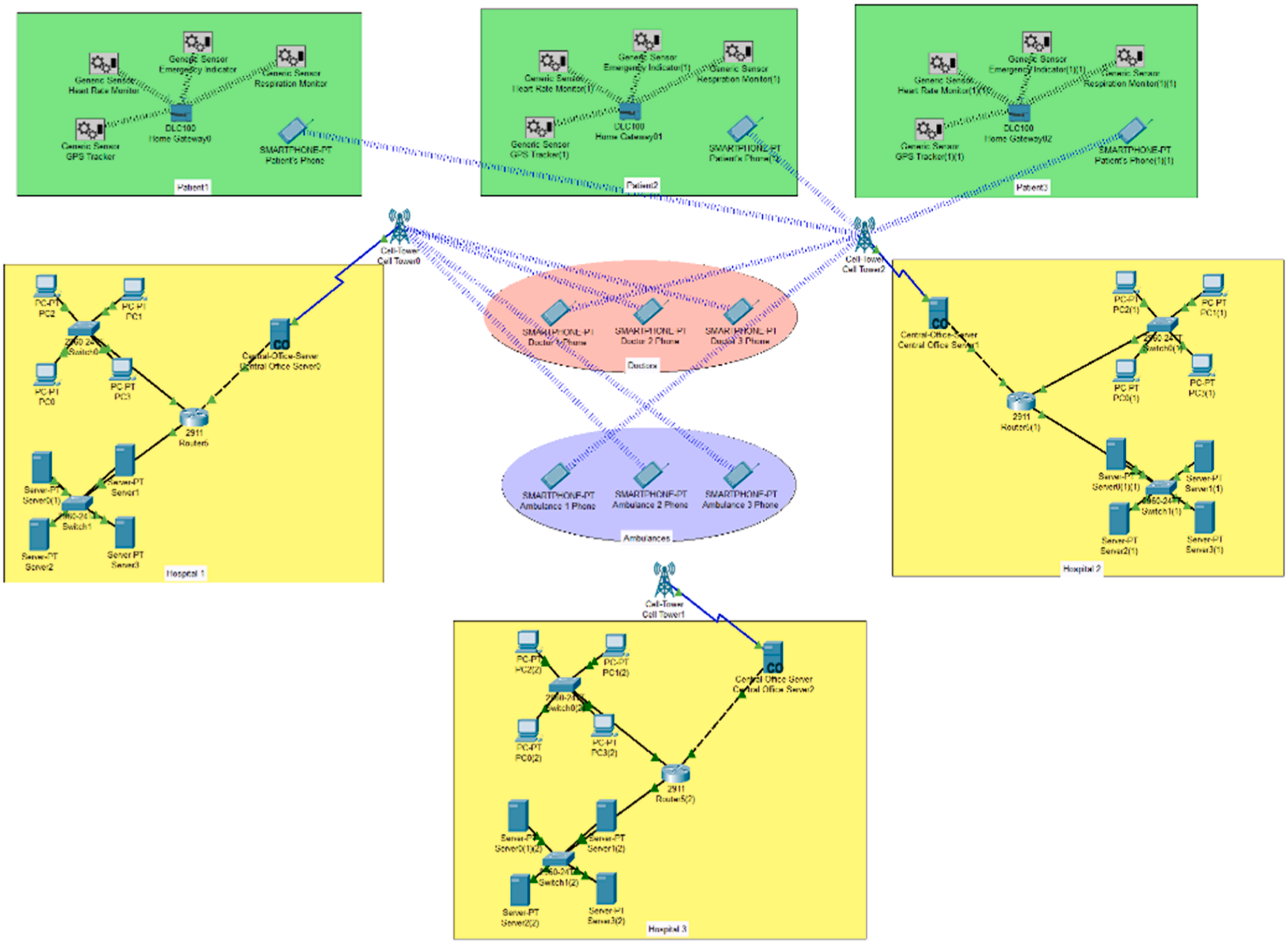

Fig. 13. Level 1 IOT Architecture of simulated environment (i.e Communication of data stream in simulated environment).

initiated, the doctor has the option to either accept or reject it based on their availability. If the doctor is available, the trigger is sent to the nearest hospital, notifying them to prepare a bed for the patient. In case the doctor rejects the call, the message is forwarded to the next nearest doctor or an assistant doctor at the hospital. Figs. 13 and 14, elaborate on the hospital's infrastructure includes three separate local area networks, each divided by routers. One network contains servers, another network comprises PCs where administrators constantly monitor emergency/trauma situations. The third network is connected to a central server, which communicates with a cell tower for data transfer between various points. Through this comprehensive communication model (Fig. 16), our research aims to ensure timely and efficient care for patients during emergencies. This model seeks to enhance healthcare delivery and improve patient outcomes in critical situations by leveraging modern technologies and network communication.

The simulation results obtained from Cisco Packet Tracer offer valuable insights into the feasibility and functionality of the proposed communication system. During this PEP, a complete software solution for patient management, hospital management, and emergency management with cloud backup and IoMT to receive/send/save patient details and important data will be extremely useful. Furthermore, as shown in Fig. 9, the software will act as a conduit between the patient, the doctor, the ambulance, and the hospital. To manage time and life savings for those in need, software must be simple to use, affordable, and powerful in terms of communicability for doctors, ambulances, and hospitals. It must be compatible with both Windows PCs and Android mobile devices. Following the above-mentioned conceptual method Fig. 9, an upgrade of the software app to obtain additional information about nearby hospital - bed and oxygen availability during COVID must be desirable. As per the conceptual design process, keeping track of post covid patients through wearable sensor and software application via IoT will be very challenging, but life saving for sudden breathlessness attacked patients in this present PEP situation.

From the provided model, Figs. 13 & 14, we can infer the following:

- **Number of Patients:** The model involves three patients, each equipped with sensors connected to their smartphones to monitor their vital readings.
- **Nearest Doctor and Ambulance**: The nearest doctor available for emergency calls is referred to as "Doctor1," and the nearest ambulance is labeled as "Ambulance1." These entities are likely strategically positioned to offer rapid assistance to patients in their vicinity.
- **Nearest Hospital:** The closest hospital to the patients and the mentioned entities is "Hospital 2." This hospital is likely well-equipped to handle emergency cases and is geographically located near the patients, doctor, and ambulance.
- **Additional Doctors and Ambulances:** In addition to Doctor1 and Ambulance1, there are Doctor2 and Doctor3, along with Ambulance2 and Ambulance3, stationed around "Hospital 1." These additional doctors and ambulances are likely designated to cater to emergency situations around that hospital.
- **Hospital 3:** Hospital 3 is relatively distant from the other entities, including patients and nearby doctors and ambulances.

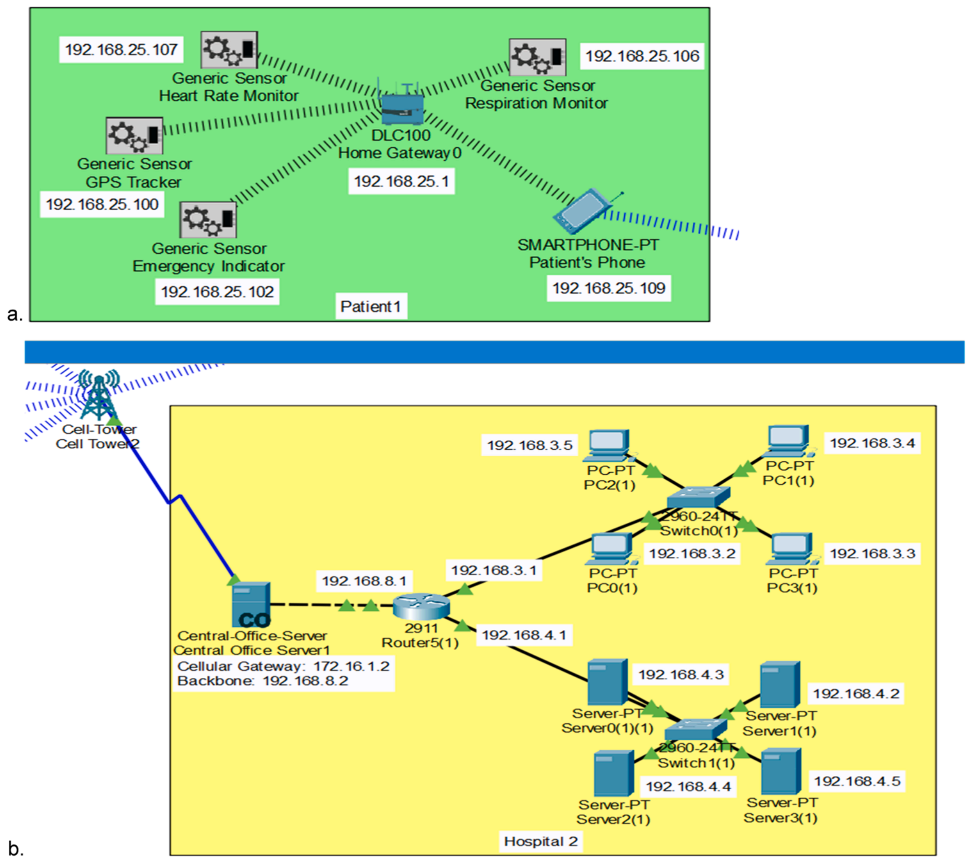

Fig. 14. Level 2 Architecture of a). Patient communication And b). Hospital communication.

This suggests that patients in proximity to Hospital 3 might face challenges in receiving immediate medical attention during emergencies. Overall, the model appears to emphasize the importance of having strategically positioned doctors and ambulances to cater to emergency situations promptly. Additionally, it highlights the significance of the nearest hospital's location for ensuring timely and efficient healthcare services during critical incidents. Hospital 3′s distance from the other entities underscores the potential challenges in providing rapid care to patients in that specific area.

SIMULATION-1: PACKET TRANSFER FROM PATIENT'S HEART RATE MONITOR TO PATIENT'S SMARTPHONE

The presented simulation (Fig. 15) demonstrates the transfer of data from the patient's Heart Rate Monitor to their smartphone. The simulation panel indicates the source (Heart Rate Monitor) and the destination (Patient's Smartphone) of the message, along with the corresponding timestamp. The total time required for the data transfer is recorded as 0.027 seconds. In figure 15.a we can see the data transfer between provided IP address, where in 15.b and 15.6, we can see the time required starting from 0.004 sec to 0.027 the whole list of information of packets transfer In detail. It can be inferred that the communication between the Heart Rate Monitor and the patient's smartphone is efficient, with minimal latency.

SIMULATION-2: PACKET TRANSFER FROM PATIENT'S SMARTPHONE TO DOCTOR1 AND AMBULANCE1

In this simulation (Fig. 16), data is transmitted from the patient's smartphone, acting as the source, to Doctor1 and Ambulance 1, who serves as the destination.

The timestamp on the simulation panel confirms that the total time required for the data transfer is 0.246 seconds. It is essential to consider that the data transfer time may vary depending on factors such as the distance between Doctor1 and the hospital or ambulance and the hospital travel distance. Other factors that can influence the data transfer time include the efficiency of the communication network, signal strength, and potential network congestion.

SIMULATION-3: PACKET TRANSFER FROM AMBULANCE1 TO HOSPITAL CENTRAL SERVER

In this simulation (Fig. 17), data is transmitted from Ambulance1 to the Hospital Central Server in real-time. The total time required for the data transfer is remarkably short, at just 0.034 seconds.

The purpose of this data transmission is to enable continuous tracking of the ambulance's location and the patient's status. The Hospital Central Server receives critical information from Ambulance1, facilitating timely monitoring and efficient medical coordination. With such rapid data transfer, medical staff at the hospital can stay updated on the ambulance's progress and the patient's condition in emergencies.

SIMULATION-4: PACKET TRANSFER FROM HOSPITAL CENTRAL SERVER TO HOSPITAL PC/SERVER

The time required for packet transfer from the central server to the PC is calculated as the sum of two components: 0.002 seconds for central server to router + 0.004 seconds for router to PC. This combined time of 0.006 seconds is achieved (Fig. 18) because the communication interface used is a wired connection, which is known for its faster data transfer rates compared to wireless communication.

The wired connection offers a more reliable and stable medium for data transmission, resulting in reduced processing and latency times. As a result, the packet can be transferred swiftly from the central server to the PC, allowing for efficient and responsive data exchange.

From the above simulation results from the CISCO tracer model, it is evident that the total time taken for sensor data to be transferred from the patient to the nearest hospital PC is 0.313 seconds. It's important to note that this time excludes the duration taken by the doctor and ambulance to respond to their availability and any unforeseen incidents. The purpose of this simulation is to showcase the effectiveness of the communication model in facilitating swift data transfer between the

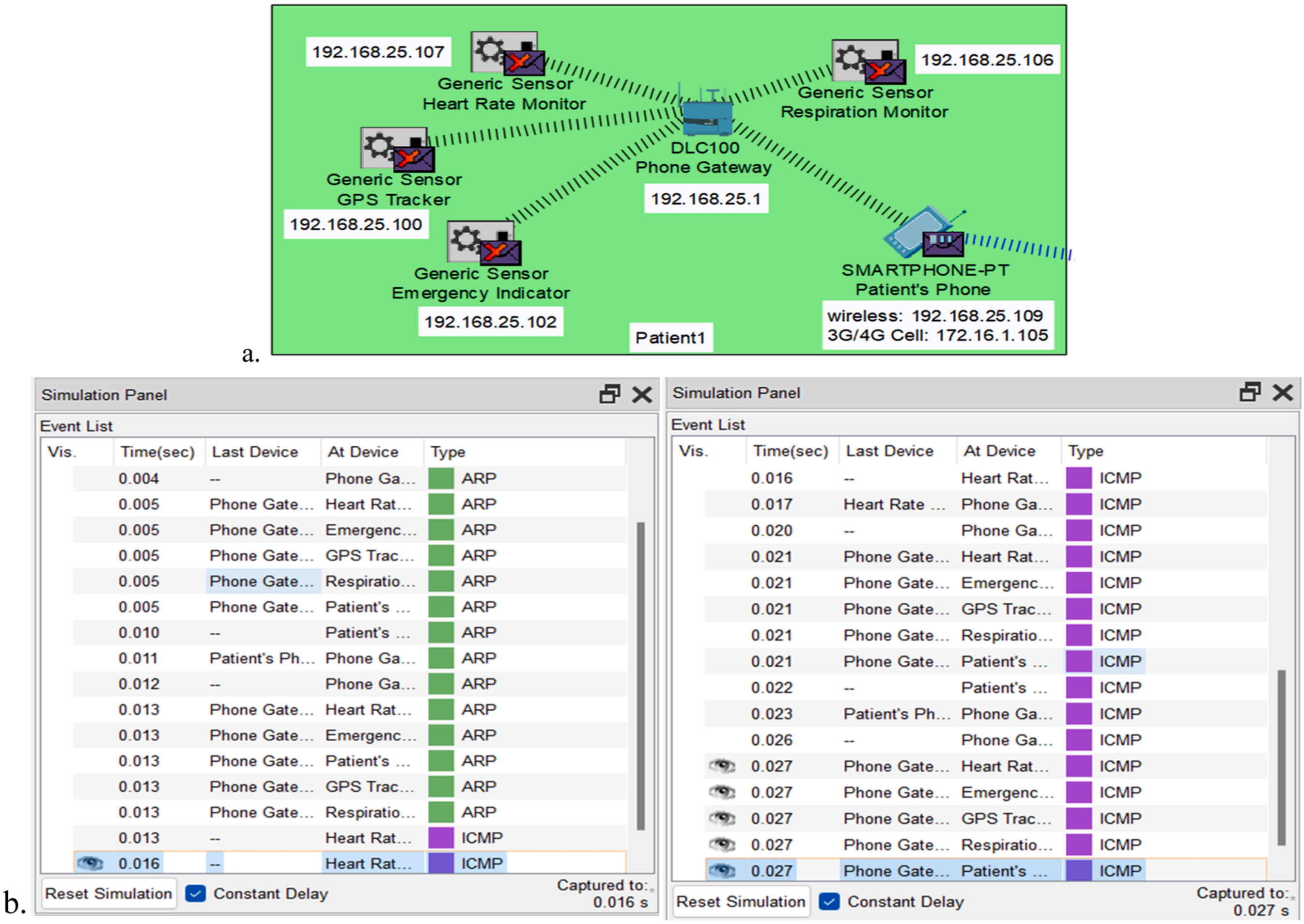

Fig. 15. Packet Transfer from Patient's Heart Rate Monitor To Patient's Smartphone.

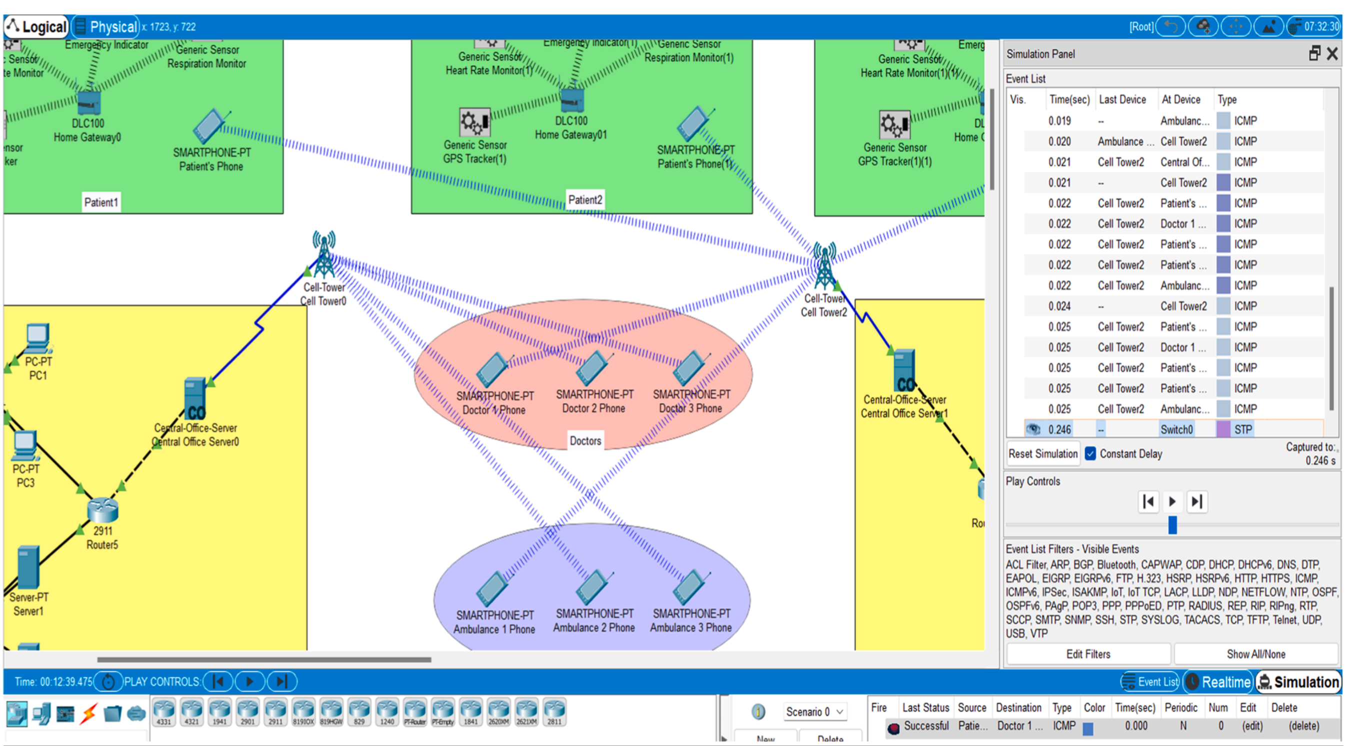

Fig. 16. Packet Transfer from Patient's Smartphone to Doctor1/Ambulance1.

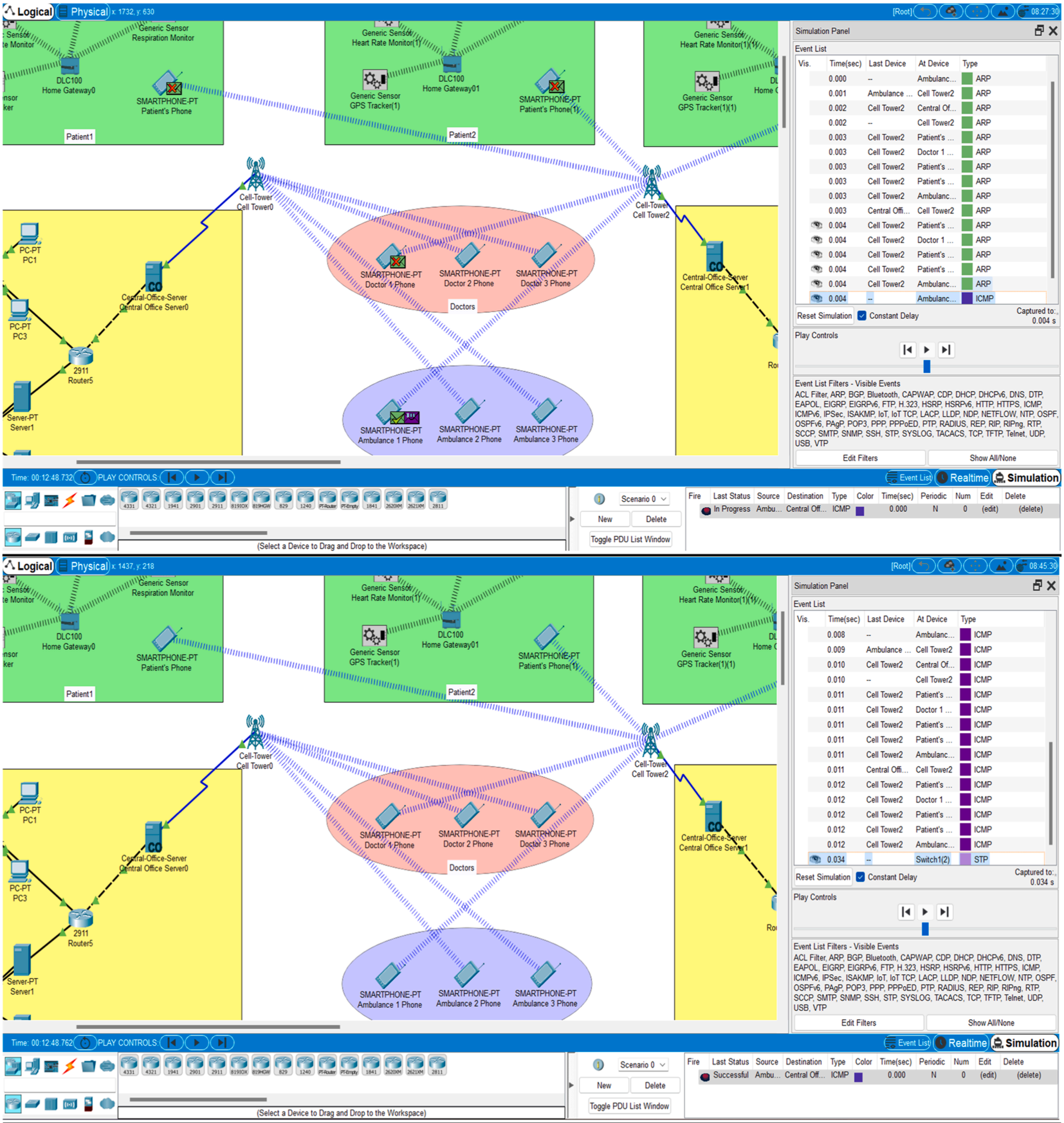

Fig. 17. Packet Transfer from Ambulance1 to Hospital Central Server.

patient and the hospital PC. By achieving a relatively low transfer time, the model demonstrates the efficiency of the communication system in transmitting crucial sensor data in real-time. Nonetheless, the results from this simulation model provide valuable insights into the capabilities of the communication model, supporting its potential for enhancing healthcare delivery and enabling effective data exchange between patients and medical facilities.

6. Expected results of conceptual design process

The changes due to the IoMT usage in hospitals are anticipated below in relation to manual care.

- **Proactive treatment:** We are becoming more aware of the epidemiology with the differential diagnosis of the infection. The best method of treatment and origins of the virus is still unknown. Constant data monitoring of health may open new gates for constructive hospital care and patient's health updates.
- **Quicker diagnosis:** Early diagnosis based on epidemiological history and clinical manifestations, or before breathing illness develops on the basis of corona virus affected symptoms, can be aided in prolonged patient data tracking and changes in real-time data through the proposed wearable strain sensor system. At minimum one of the below mentioned characteristics must be observed for diagnosing extreme PEP: (i) shortness of breath (respiration rate $\geq$

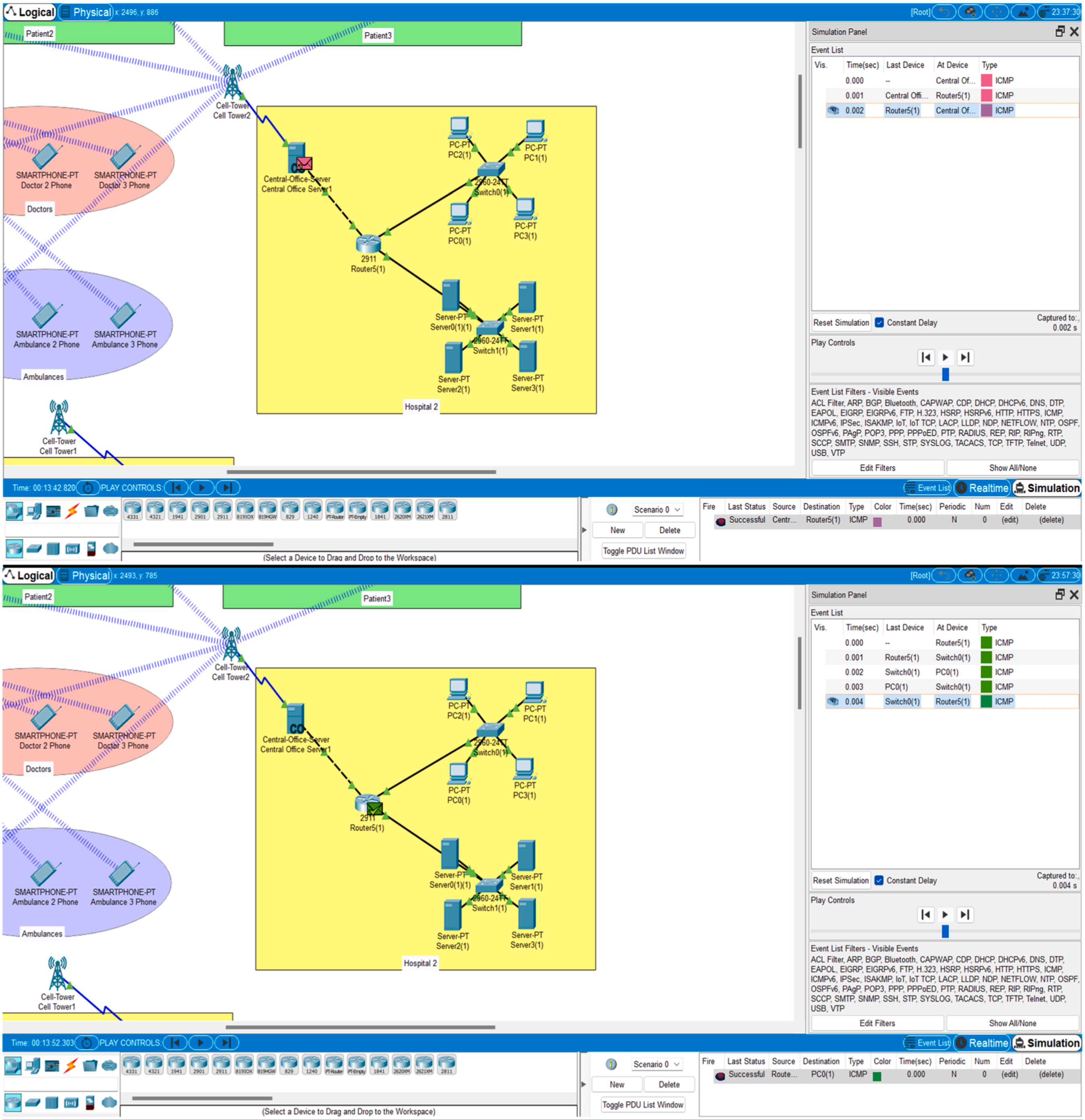

Fig. 18. Packet Transfer from Hospital Central Server to Hospital PC.

30 BPM); (ii) depletion of arterial oxygen nearly 93 percent; (iii) the proportion of oxygen while partial compression to the fraction of oxygen of inspiration (PaO2/FiO2) to a rate of 300 mm Hg.

- **Strengthened medication:** It allows doctors to make brief decisions on the basis of evidence but also tends to bring supporting information for the cure. Method for the easy identification and separation of patients, as a proof of suspected PEP cases, a traffic control hooking should be in effect, with multiple Airborne infection isolation rooms established in the different locations inside the hospital. Installation of wearable strain sensors for infected patients will be a better choice to keep track of their respiratory information up to date.
- **Effective time management:** The efficient handling of medicinal products and medical devices is a major healthcare industry hurdle. These are successfully controlled and used with decreased expenses and delays via smart devices. Consistent and correct use of environmental sanitizing and disinfection methods is accomplished by this information's time-sensitive nature. IoMT provides real-time patient surveillance, hence if any variations in the breathing rate or volume of the patient, the respective alarm will be a time saving factor for the doctors to reach and diagnose the necessary actions.
- **Reduced costs:** As IoMT services enable real-time continuous patient observation via portable wireless sensors, hospitals are gradually reducing their reliance on heavy equipment. Making availability of easily implantable kits or portable device sets would be of less

cost, like presently available portable, sugar testing kits, Blood Pressure testing kits, pulse rate checking device, body temperature checking device etc.
- **Reduce inventory:** IoMT data not only contributes to fast and effective decision-making, but also provides smooth healthcare work with significantly lower errors, trash, and platform expenses. For better case study and therapies, the slope of linear regression of today's breathing rate set to a few days earlier could be measured from the acquired data[37].
- **Decreased death rate:** Sudden breathlessness because of the virus infection during PEP it has become a major trigger for causing deaths. According to the WHO survey mentioned, the death rate is maximum. Because of the vast spreading of the virus, it focuses first on throat and lung to infect easily and affecting the respiratory system gradually. The above-mentioned system method may rescue people from dying of breathlessness, as time is critical in this situation.

Proposed conceptual design process implementation and practical usage of it on patients may be the better solution to obtain the decreased death rates in this pandemic scenario.

7. Conclusion

In the proposed conceptual design, three different types of inputs are considered, heart rate variation/respiration rate variation / mobile app through indication. But detailed the wearable synchronized breathing detection sensor system plays an important role in addressing technical challenges (such as: power consumption, accuracy, reliability and consistency) and physical challenges (such as: wired connections, placement of sensor according to the body size, slippage during movement) accordingly. This paper highlights the portable and wearable strain sensor equipped to calculate the breathing rate and volume of a human respiratory system and allows us to track the data of multiple patients breathing data online via Internet of Medical things (IoMT) during PEP through software application. The simulation results of RR signal conversion and alarm indications are illustrated. Through simulations using Cisco Packet Tracer, the proposed system's efficiency in processing data has been demonstrated. Additionally, alert indications have been successfully generated based on respiratory rate data, providing essential information to both healthcare professionals and the public. Also, it will be lifesaving even after the patient gets declared as negative and get discharged from the hospital to keep track of breathing variations to avoid the death cases because of breathlessness. Our report would provide a basis for medication management and planning for respiratory related issues during PEP.

CRediT authorship contribution statement

Spoorthi Singh: Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Mohammad Zuber:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis. **Navya Thirumaleshwar Hegde:** Writing – original draft, Validation, Software, Resources, Methodology, Investigation. **Meet Hitesh Jain:** Writing – original draft, Validation, Software. **Mohd Nizar Hamidon:** Writing – review & editing, Supervision, Project administration, Investigation. **Adi Azriff Basri:** Writing – original draft, Supervision, Project administration, Data curation. **Norkhairunnisa Mazlan:** Writing – review & editing, Visualization, Validation, Software, Project administration. **Kamarul Arifin Ahmad:** Writing – review & editing, Visualization, Supervision, Project administration, Investigation, Conceptualization. **Ramya S Moorthy:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This work was supported by the University Putra Malaysia and Manipal institute of technology- MAHE-India. We would like to thank all those who have contributed to this work wholeheartedly.

Data availability

Data will be made available on request.

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