Tracking Infected Covid-19 Persons and their Proximity Users Using D2D in 5G Networks

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***Abstract*—The world witnessed a pandemic that needs to be limited. COVID-19 is a disease that spreads among people when an infected person is in close contact with another. To decrease the virus spreading, World Health Organization (WHO) imposed precautionary measures and suggested some rules to be followed such as social distancing and quarantining the infected people. We propose a model, using D2D and IoT technology, for tracking infected persons with COVID-19 and its proximity. If a person (mobile device) gets close to an infected person, he will also get infected, so by continuous moving, the infection will be transmitted. Thus, identifying the infected persons and their contacts will limit the spread of the disease. In each scenario, it is possible to distinguish the number of infected people and know from whom they are infected, and the location of the infection. The simulation shows the tracking of a mobile device when proximate infected person at a distance of 3 meters. As a result, our proposed D2D model is effective, especially in the scenario which found the infected person with COVID-19, tracks them, determines minimum distances, and recognizes the source of the infection. Thus, the model can limit the rapid spread of COVID-19 as it determines the 3meters distance from infected person and send precaution messages to the network.**

***Index terms*—Covid-19, D2D, 5G, Proximity.**

I. Introduction

Current 4G technology cannot meet customer expectations given the quick rise in connected devices, traffic volumes, and application requirements. The 5G mobile network aims to combine fundamental fixes for existing issues and enhance communication architecture to accommodate more users. It offers faster data rates, greater capacity, and reduces control traffic and latency. Compared to the earlier mobile networks, 5G networks are anticipated to be far more dynamic and densely distributed.

The Internet of Things (IoT), is a potential paradigm that combines several technologies and communication options, which will be supported by widespread network deployment on 5G networks. There are several technologies included in this, such as Device to Device (D2D) communication, huge Multiple-Input Multiple-Output (MIMO), and Carrier Aggregation [1].

Device-to-Device (D2D) communications refer to direct connection between devices (i.e., users) without data traffic going via any base station. These have generally been projected to be a key component of the upcoming 5G system for boosting the performance of the system and enabling additional services after 2020. In general, D2D operation has several advantages, including greater spectrum efficiency, increased normal user data rate with capacity per area, broader coverage, decreased delay, and improved power efficiency and cost [2].

COVID-19 was identified in December 2019 in Wuhan, China. It affects the respiratory system of humans and transmits both from human to human and from animal to human [3]. Early identification of positively infected is vital for their treatment and containment of the infection [4]. 5G technology could assist us in enhancing diagnostic capabilities in high-risk areas. This is achieved by locating infected individuals as soon as possible, tracing their contacts, to identifying the source of the infection, thereby preventing viral spread [5]. To limit the break-out of COVID-19, it is very important to perform massive tests, inform the infected persons, and lock them down. Sometimes, a person will not follow the authority's precautions and leaves home, and as a result, he infects others. In this case, it is urgent to assign each infected person and broadcast their names in order not to allow the virus to break out and cause a disaster.

Tracking people wirelessly starts by creating an account for them, whether they are infected or not. Giving each person their unique identity (ID), internet protocol (IP), and international mobile subscriber identity (IMSI) address of their mobile operator. The user ID is usually random according to a predefined random number generator in the user's device, thus maintaining the confidentiality of the user's ID. Information and data are stored on the server either centrally or in a distributed form. In the centralized model, the user uploads their data to the cloud server, and health authorities can track and check their contacts. In the distributor model, data is stored locally and allows users to check if they are in contact with people nearby or not. The second type is characterized by giving more privacy to people. As for the first type, it gives health authorities more

Manuscript received September 1, 2022; revised November 28, 2022. Date of publication January 30, 2023. Date of current version January 30, 2023.

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Digital Object Identifier (DOI): 10.24138/jcomss-2022-0103

information about the spread of the disease and is faster in detecting the infection spread. If someone shows signs of illness like temperature, cough, etc. If takes a COVID-19 test and the test result is positive, the operator will send the result of his tests to the cloud server.

The server sends his data to all the governmental organizations and alerts people who are less than a 3m distance from him. The health authority asks them to quarantine, which case will prevent the spread of the Coronavirus further [6].

In this paper, a mobile application is proposed to track infected people with Covid-19 using D2D communication technology, to detect and track the movement of people when approaching an infected person or, vice versa, at a distance of 3 meters or less. It is possible to follow their movements and know the people who are in contact with them. Thus, reducing the infection and limiting its spread.

The paper is organized as follows. Section II presents the literature on D2D communications and suggests some approaches for COVID-19 tracking applications. Section III explains the proximity services and device discovery for the D2D technology. Section IV explains the design of a COVID-19 person tracking application developed by using D2D Communication. Section V presents the analysis and results. The conclusion is in section VI.

II. Related Works

The COVID-19 pandemic has heightened the demand for technical solutions that are capable of tracking people's contacts and providing location-based data. Several developing centers have implemented proximity-based (short-range) technologies such as Bluetooth, however, they appear to be hampered by deployment challenges, security leaks, a lack of dependability, and data governance concerns.

This section shows some of the research that is conducted on D2D technology, and even some potential solutions for COVID-19 contact tracing. In [7], the authors introduce how cellular networks can be exploited for contact tracing, especially as 5G networks play an essential role in contact tracing and monitoring of accurate location awareness. In [8], the paper shows a COVID-19 contact monitoring application based on D2D communication, where Wi-Fi Direct is utilized to trace the region's contacts and explore comparable approaches that are created with a focus on Google and Apple exposure alerts. In [9], the authors discussed how 5G, IoT, and related technologies can be used to combat the COVID-19 pandemic. Use cases in healthcare, contact tracing, self-isolation, online learning, and other areas have been discussed, as well as how various elements can be used to create creative solutions suitable for a post-COVID-19 era. Also, it discussed how to deal with the issues as well as solutions for security and privacy, scalability, limited connectivity, societal issues, and legal issues. In [10], the paper proposed a model based on Lagrange optimization and a distributed deep learning model. Which is intended for use in closed places, where the radio frequency identifier (RFID) tag could detect and track any COVID cases. Lagrange optimization and a distributed deep learning model are connected to an RFID reader for accurate and efficient tracking. An RFID reader's role is to collect different necessary data for COVID-19 diagnoses, such as temperature, and detect the distance between any two people. In [11], the research looked at the potential of emerging technologies like 5G and 6G communication, Deep Learning (DL), big data, the Internet of Things (IoT), and so on for attempting to control COVID-19 propagation and trying to ensure health safety. This study has identified areas of application for COVID-19 management: infection detection, travel history analysis, the identification of infection diagnoses, early detection, transmission identification, and the development of medical treatment methods and vaccines. In [12], the authors present a comprehensive knowledge of social distancing, including basic concepts, metrics, models, and the proposal of different practical social distancing scenarios. Then, they explain enabling wireless technologies that are particularly effective and can be widely used in real life to maintain spacing, encourage, and enforce social distancing in general. Following that, other emerging technologies such as machine learning, computer vision, thermal, etc. are discussed. These technologies provided several solutions and directions for dealing with social distancing issues. In [13], the paper presents COVICT, an IoT-based COVID-19 detection, and tracking system with semi-automated and improved contact tracing capability, with the application of real-time data of symptoms gathered from individual people and contact tracing. By imposing Smart Lockdown, COVICT can enhance the prediction of infected people and identify environmental contamination to prevent further virus spread. The suggested IoT-based design can be quite useful for regulatory agencies in developing policies to combat COVID-19. In [14], the paper assesses the efficacy of recent advanced COVID-19 contact-tracing smartphones that use Bluetooth to discover contact details. It investigates how these applications operate to simulate the key factors influencing their performance: accuracy, tracing speed, and implementation design.

Compared to the proposed model here, in Ref. [14], the main benefit of D2D communication is to search for nearby devices and connect with them without passing through BSs, offloading congestion from the network. As Bluetooth demands users to keep their devices open and active, the Bluetooth option keeps contacting every while so that they remain visible to other peers. In addition, the D2D technique has a high data rate, and a transmission range of up to 100m that gives the exact locations of the devices, while Bluetooth has low data rates suitable for small data, and a transmission range limited to up to 10m.

In this paper, a mobile application is proposed for tracking people infected with the COVID-19 virus. By using D2D communication technology to detect nearby devices, one can determine: who is in contact with the infected persons, their location, and the distance between them, follow their movements, and identify the people who transmitted the infection to them.

III. Proximity of Service (ProSe)

In the 3GPP LTE Release 12, systems included D2D communications technology. The use of D2D communications among users (UEs) close is projected to increase spectrum efficiency, total throughput, and energy consumption. Also, it ensures improved public health and safety network services [15]. Proximity-based Services (ProSe) are intended for both public safety and commercial uses, while the emphasis in Rel. 12 is solely on public safety [16]. The two fundamental functionalities for enabling 3GPP ProSe are D2D discovery and communication [17]. ProSe discovery enables a UE to utilize the LTE air interface to locate other UEs in the vicinity. There are two types of ProSe discovery: open and restricted; the distinction is whether or not the authorization is required for UE discovery [15]. Open discovery requires no express approval from the UE being discovered, whereas limited discovery requires express approval from the UE being discovered [18]. ProSe communication occurs when two UEs that have discovered each other connect directly over the LTE air interface, bypassing the eNodeB (eNB) and the core network [19].

A. Architecture of ProSe

The ProSe architecture consists of three major components that enable D2D communication known as ProSe Application, ProSe Application Server, and ProSe Function as shown in Figure 1.

- ProSe Application: The UE hosts the ProSe Application. This component is in charge of D2D communications both for data and control messages. A ProSe Application, for example, can transmit beacons to identify new nodes or submit its position information to the Evolved Packet Core (EPC) and request network help during the discovery phase. Furthermore, following discovery, the ProSe Application manages the D2D data connection between two UEs.
- ProSe Function: acts as a basis of reference for the ProSe App Server, the EPC, and the UE. The features and functionality may include: (1) internetworking through a point of reference to third-party applications; (2) permission and configuration of UEs for discovery and direct communication; and (3) enabling EPC-level ProSe discovery, charging, permission, UE configuration, and safety.
- ProSe Application Server: The ProSe App server is made up of ProSe's core features (for example, public safety responding point or PSAP) that are utilized for public safety or other business use cases. The application server can connect directly with a UE-defined application that is normally built outside of the 3GPP framework [20].

B. Device Discovery

One of the most critical processes in cellular D2D communications is device discovery, which detects device proximity [21]. The first phase in D2D communications is device discovery, also known as peer discovery. The device The device attempting to create a D2D communication must be able to locate other adjacent devices in a reasonable amount of time. The devices can only be detected if they are close by and desire to be discoverable. In this case, the devices that want to communicate will broadcast beacon signals to surrounding network devices, as illustrated in Figure 2. Devices that are ready to join a D2D network will respond to the beacon signal with their position, channel status information, and distance details [22].

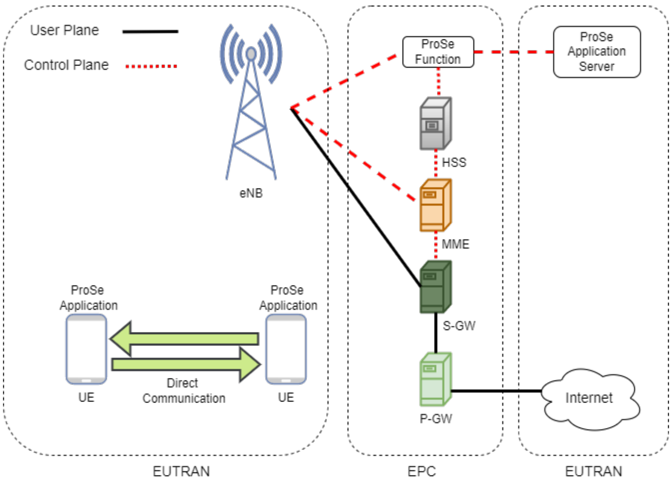


Fig. 1. D2D communication-based architecture of 3GPP ProSe.

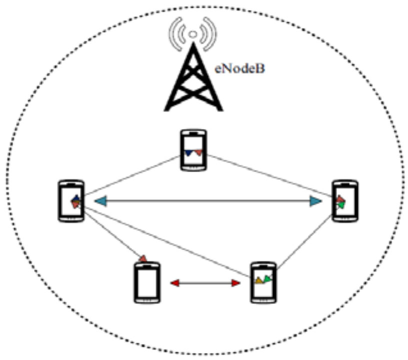


Fig. 2. Device Discovery

A device discovery technique is categorized into two types: centralized device discovery and distributed device discovery. The centralized entity, which is frequently a base station or access point, helps devices in the centralized device discovery to recognize one another. The base station initiates the signal exchange between two devices to get essential information such as channel state information, power, and interference management rules based on system requirements. A base station's participation in the device discovery process might be whole or partial, depending on the pre-designed suite of protocols. If the base station is completely incorporated, the devices aren't allowed to begin device discovery with each other. The base station facilitates each device's discovery signal. In this case, the devices simply check in with the base station's discovery signals and broadcast discovery signals to initiate the device discovery operation. If the base station is only partially integrated, the devices send device discovery signals to one another without obtaining permission first from the base station. However, each device has a base station that exchanges the Signal to Interference Noise Ratio (SINR) and path gain. This supports the base station in determining the feasibility of the device connection. Finally, the base station requests that both devices commence communication. Distributed device discovery approach allows devices to discover one another without the need for a base station. The device that wishes to commence communication begins to search for other devices in its vicinity. For D2D communication, beacon signals are delivered and information about the location, channel state data, and device availability status is transferred between the devices. To discover the surrounding devices, the gadgets send control signals sporadically.

However, interference, timing difficulties, and the strength of the discovery signal are frequently encountered in the dispersed form [23]. As a result, In-band device discovery is effective in all aspects of D2D design. Many additional device discovery systems for In-band and Out-of-band have been developed based on the centralized and dispersed categories, as illustrated in figure 3. The network-based device discovery, direct discovery, and beacon-based discovery are In-Band, while the others are Out-of-Band.

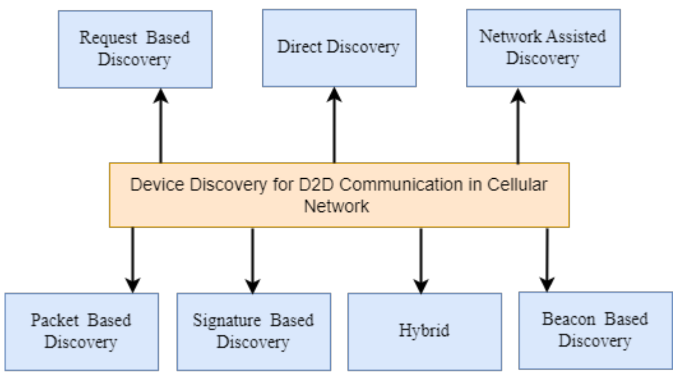


Fig. 3. Situations involving In-Band and Out-of-Band device detection in D2D communication.

A pilot or beacon signal is sent to locate other nearby devices. The pilot signal includes scheduling information, which might be problematic if the information it transmits is incorrect. Unless an acceptable device is located, the beacon signals are sent often and again. This repeated transmission of beacon signals may create interference with other network devices. The beacon broadcasts cannot also be infrequent, since this may delay the finding process when the neighboring device state changes owing to device movement. Synchronization is another key challenge in D2D communication. All network devices are synchronized with the base station. The scheduled time is set by the base station. When two devices are transmitting data and one of them is detected to be out of range of the base station, the network must continually search for additional nearby devices [22].

IV. D2D Simple Mode for Tracking Infected Person Covid-19

A. System Model

In the presence of the contagious disease COVID-19, social distance is a non-pharmaceutical method of limiting disease transmission. Social distancing refers to measures for limiting the proximity of human physical contact, such as closing public venues (for example workplace, schools) and keeping an appropriate space between persons. Social distance can greatly minimize disease spread by lowering the likelihood that the virus could be passed from an infected person to a healthy one. The primary premise of social distancing is to increase the distance between individuals by more than 3 meters. Techniques to establish the locations of people and measure the distance may play an essential part in aiding social distancing measures. Many social distancing scenarios could help reduce the spread of infections. These often include distance keeping, tracking people's mobility, identifying the people who approached the infected person at a short distance, tracking their movements, and alerting them to the necessity of sanitary isolation.

This paper proposes a model and designs a method to track the movement of people using D2D technology and monitor the movement of persons. If any person approaches another infected one at a distance less than three meters away, the infection is transmitted to him without his knowledge. As he keeps moving he may cause other people to be infected as well. Here it is possible to identify the location of the infected person constantly, follow his movements, recognize the people to whom the infection could be transmitted, and inform them of the necessity of quarantine to limit the spread of the Coronavirus, as shown in Figure 4.

Contact tracing is regarded as one of the important public health measures for controlling COVID-19 spread. It aids in the identification of individuals who have been exposed to a confirmed COVID-19 case.

Smartphones are now equipped with advanced sensors, GPS, connectivity (Bluetooth, Wi-Fi), and other features that make them ideal for contact tracing. Because people carry it with them most of the time, it can be used to capitalize on mobile features and aid in contact tracing. The system architecture of tracing is divided into four basic steps as shown in Figure 5.

1. Registration: register a user in a cloud server and provides details and information.
2. Contact information: when a registered user approaches another user, they contact each other through D2D communication, thus, it is possible to distinguish their locations and the distance between them.
3. Update data: when a user is diagnosed positive, the health authority uploads the state to the server for processing, and sends the result to the user.

4. Contact tracking: the server processes the information and searches for people in contact with the infected person through D2D technology. Then, the health authority is alerted, which in turn warns the user and asks him to quarantine.

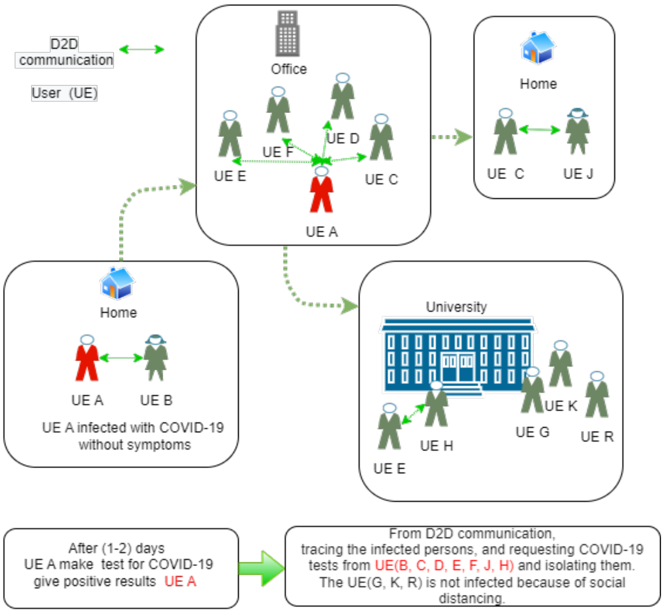


Fig. 4. Tracking the movement of one person and knowing the people in contact with him.

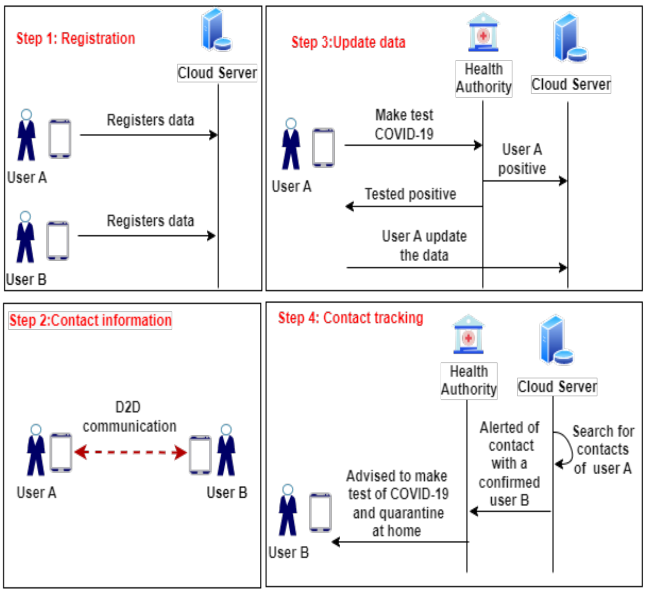


Fig. 5. COVID-19 Contact Tracking.

In the simulation, the model starts when a person is infected, he makes a test for COVID-19, and the result is positive, so he sends the result to the cloud server to inform it. The system will monitor and track the device and gets the minimum distance using a D2D chart with the infected person. Anyone close to the minimum detection proximity will be set to be infected as well, and the model will track his device. Assume that a pair of UEs D2D, an infected UE (TX) transmitter, and a healthy UE (RX) receiver are connected using D2D technology directly without the need for a base station (gNB) inside a building, the UDP protocol is used for communication. In addition, the number of healthy people UERX1[numUE] is 5, 10, and 20 distributed randomly each time on the cell simulation area of 100m x 100m, the initial distance between the D2D users of communication is 40m, and the distance between the users and the base station is initially 50 meters before moving. The model was tested and analyzed using OMNET++ simulation, INET framework, and Simu5G software, as shown in Figure 6.

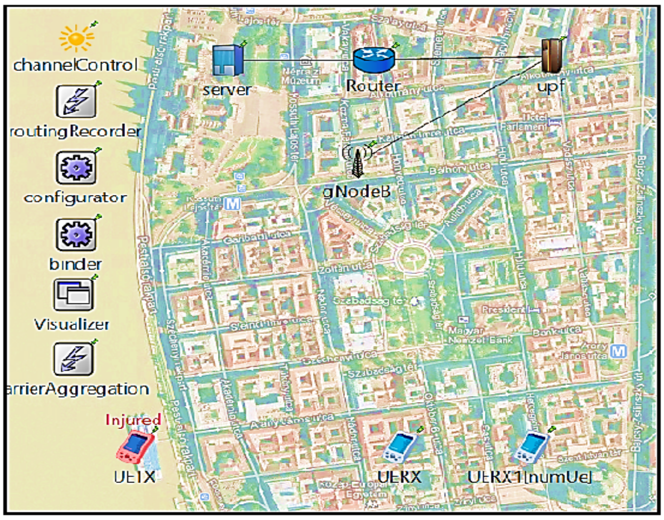


Fig. 6. Simulation D2D communication in OMNET++.

Suppose a user UE (TX) is infected with covid-19 and is stationary (non-motile), the user UE (RX) is uninfected moving in two types of motion (linear and random) towards UE (TX). At the same time, the location of UE (RX) is followed at every moment. As he approaches UE (TX) at a distance of three meters or less, the infection will be transmitted to him without his knowledge and he will be classified as infected. If UE (RX) continues to move then his movement will be followed as well. Therefore it would be possible to know if he causes infection in other people or not. The following, are different scenarios for the movement of UEs:

1. Healthy users UERX1 have a fixed position, they are randomly distributed, UE (RX) moves linearly at 1.2 meters per second, the position of infected UE (TX) at point (20,80) is stationary, and when UE (RX) approaches toward UE (TX), it gets close in a very little distance. One of his movement location tracking points is 19.5,76.4. Notes that the distance is very small, it is less than a three-meter. This indicates that the Coronavirus was transmitted to UE (RX) and he continues to move, but without approaching another person during the simulation time of 150 seconds, which means that it did not transmit the disease to anyone else as in Figure 7.
2. All healthy users UERX1 and UE (RX) move linearly at an angle of 185, and a speed of 1.2 meters per second. Notes that UERX, after being infected with the

coronavirus by UE (TX) and continued his path, and did not approach the other people just like in the first case and as we see in Figure 8.

3. All healthy people UERX1 and UE (RX) move randomly. Notes that UE (RX) does not approach UE (TX) and does not get infected, but UERX1[5] and UERX1[4], approach it and get infected at the sites 23.3,75.0 and 18.17,77.7. Also, the user UERX1[5] after being infected will approach UERX1[8] and UERX1[1] and infect them at the sites 57.6,49.4 and 52.8,37.5 as shown in Figure 9.
4. All healthy users UERX1 move randomly, while UE (RX) moves linearly at 1.2 meters per second with an angle of 185 degrees towards the affected UE (TX). Notes that UE (RX) will be infected at site 23, 76.7. Furthermore, several healthy people will be infected, Table 1 shows the infection of each user, their location, and when and where they are infected. In Figure 10, some cases of convergence are shown for each infected person.

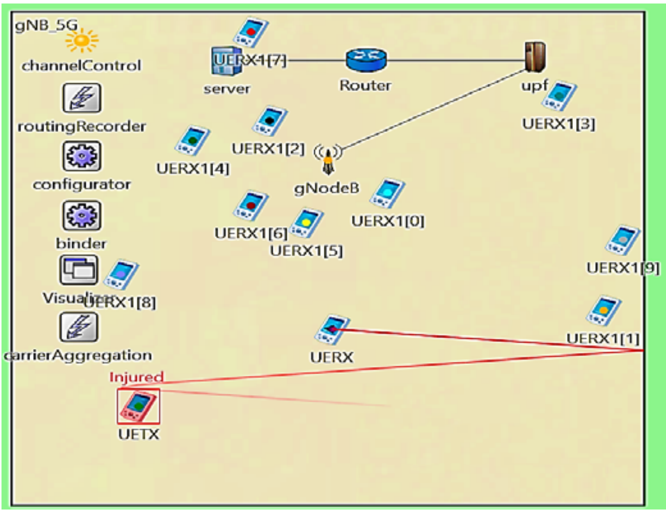


Fig. 7. The movement of UE (RX).

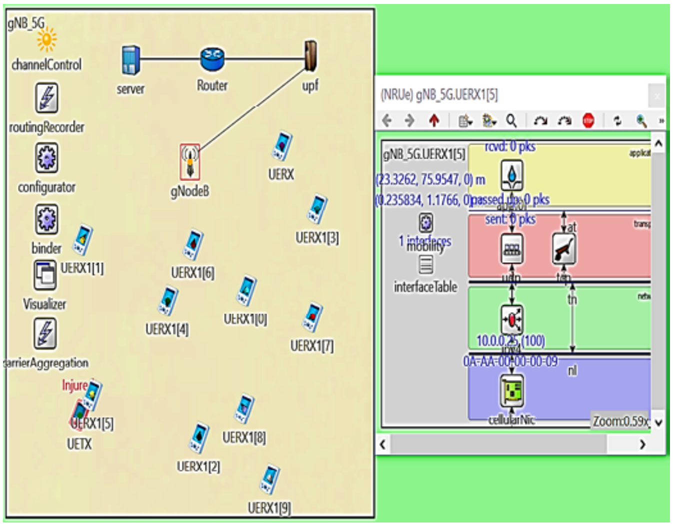
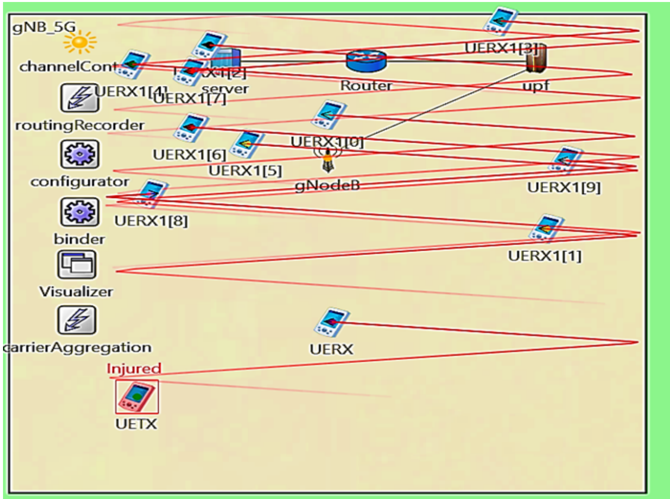
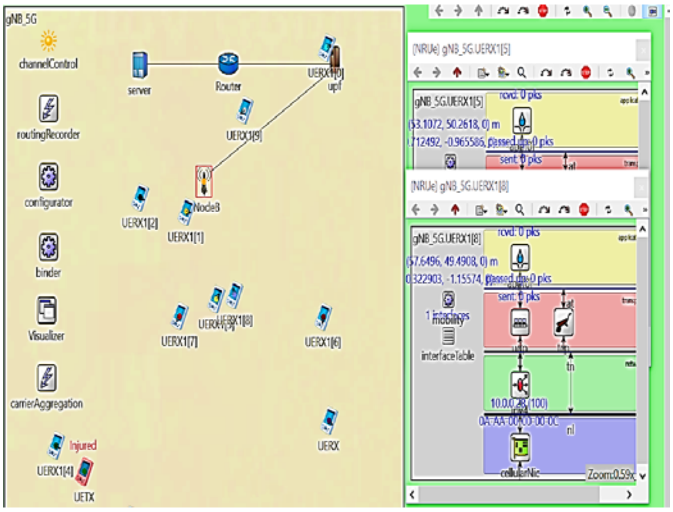


Fig. 8. All the users are moving linearly.

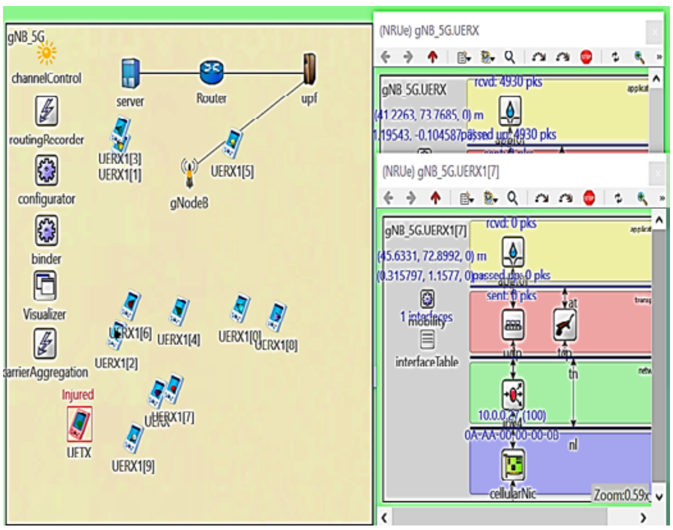


(a)

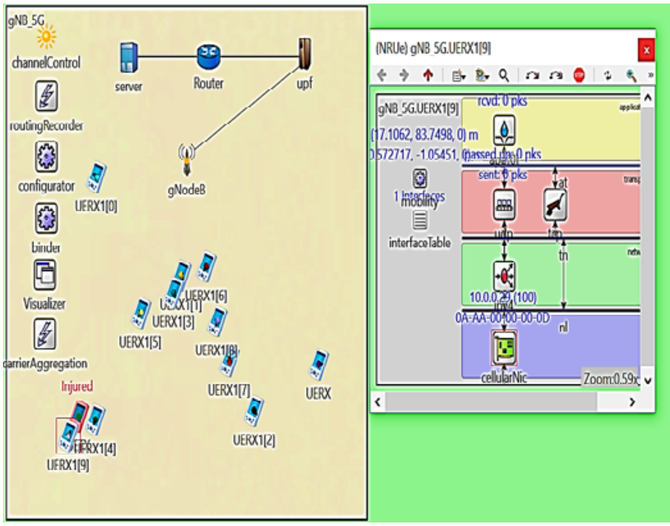


(b)

Fig. 9. (a): UERX [5] approaches UE (TX), (b): UERX [8] approaches UERX [5].



(a)



(b)

Fig.10. (a): UERX1[7] approaches UE (RX) after being infected, (b): UERX1[9] approaches UE (TX).

TABLE I
INFECTED PEOPLE FOR EACH CASE

SCENARIOS	INFECTED PERSON 1	POSITION OF 1ST PERSON	INFECTED PERSON 2	POSITION OF 2ND PERSON
CASE 1	UE(TX)	P(20,80)	UE(RX)	P(19.5,76.4)
CASE 2	UE(TX)	P(20,80)	UE(RX)	P(19.5,76.4)
CASE 3	UE(TX) UERX1[5] UE(TX) UERX1[5]	P(20,80) P(53.1,50.2) P(20,80) P(51.6,42.6)	UERX1[5] UERX1[8] UERX1[4] UERX1[1]	P(23.3,75.9) P(57.6,49.4) P(18.17,77.7) P(52.8,37.5)
CASE 4	UE(TX) UE(RX) UE(TX) UE(TX) UERX1[9]	P(20,80) P(39.1,73.9) P(20,80) P(20,80) P(48.5,40.8)	UE(RX) UERX1[7] UERX1[9] UERX1[4] UERX1[1]	P(23,76.7) P(45,72.8) P(17.1,83.7) P(23.8,82.3) P(45.7,40)

V. DISCUSSION

One of the most important factors in the spread of the Coronavirus is the proximity of people to each other at a few distances which leads to infection. It is difficult for many technologies to deal with very small distances because they do not give accurate results such as GPS technology and others. The D2D technology deals well with short distances, some meters or less. Therefore, the model can easily follow the movement of the moving person when he approaches the infected person and communicates with him directly without the need for the base station. The model tracks the movement of a user and recognizes the people he meets, and their locations at every moment by using the OMNET++ program. It distinguishes the distance between people as three meters or less; this distance is sufficient to transmit infection and disease from one infected person to another healthy one. The model proposed appears to be effective in all the cases that are taken and simulated. The model explains in each scenario the number of infected people, the exact location at each moment for each user, the movement of the users, and the distance between them if it is less than 3 meters or not. The model explains the results of when one or more users move, in addition to the type of the movement if it was random or linear at a certain angle.

VI. CONCLUDING REMARKS

The smart IoT-based framework aids in the improvement of the monitoring and contact tracing processes, providing a solution to the healthcare and medical systems. It appears that IoT establishes a global footprint, allowing it to demonstrate its potential in the technical world. D2D communication that is enabled by the cellular infrastructure has gained a lot of attention in recent years, and a D2D will undoubtedly play an important role in IoT/5G integration. D2D communications refer to the paradigm in which devices interact with one another directly rather than via a network infrastructure. COVID-19 contact tracing applications can benefit greatly from D2D communication. In this paper, a mobile health IoT application is proposed to track people infected with Covid-19 using D2D communication technology. When someone reports that they have the coronavirus and sends their ID, IP, and IMSI data to the mobile operator and the cloud server, the server processes the information and searches for people in contact with the infected person at a distance of 3 meters or less, and the disease is transmitted to them, through D2D technology, to find their location and track their movement. Then, the health authority is alerted, which in turn warns the user and asks him to quarantine. As a result, the model finds all the infected people, tracks them, identifies their exact location, and knows the people who have taken the disease, and whether the distance between them is less than 3 meters or not, therefore infection can be curtailed and reduced, and its rapid spread could be limited.

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