Minimizing Viral Transmission in COVID-19 Like Pandemics: Technologies, Challenges, and Opportunities

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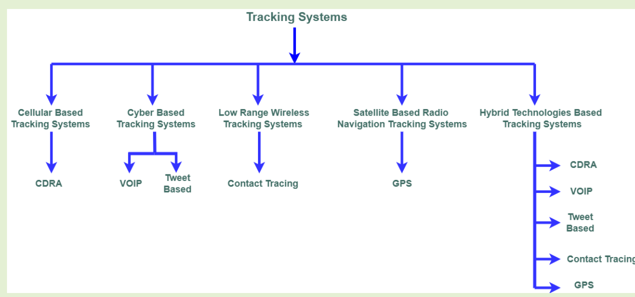
***Abstract*—Coronavirus (COVID-19) pandemic has incurred huge loss to human lives throughout the world. Scientists, researchers, and doctors are trying their best to develop and distribute the COVID-19 vaccine throughout the world at the earliest. In current circumstances, different tracking systems are utilized to control or stop the spread of the virus till the whole population of the world gets vaccinated. To track and trace patients in COVID-19 like pandemics, various tracking systems based on different technologies are discussed and compared in this paper. These technologies include, cellular, cyber, satellite-based radio navigation and low range wireless technologies. The main aim of this paper is to conduct a comprehensive survey that can overview all such tracking systems, which are used in minimizing the spread of COVID-19 like pandemics. This paper also highlights the shortcoming of each tracking systems and suggests new mechanisms to overcome such limitations. In addition, the authors propose some futuristic approaches to track patients in prospective pandemics, based on artificial intelligence and big data analysis. Potential research directions, challenges, and the introduction of next-generation tracking systems for minimizing the spread of prospective pandemics, are also discussed at the end.**



***Index Terms*—COVID-19, pandemic, cellular forensics, hidden patterns, tracking systems, artificial intelligence.**

I. Introduction

A NEW type of virus discovered in China in late 2019, named as coronavirus (COVID-19), has led to the pandemic [1], [2]. COVID-19 is the latest pandemic in human history, which is a transmissible disease, initiated by severe acute respiratory syndrome (SARS). It is a new strain, which has not been formally identified by human beings. The world health organization (WHO) has affirmed it through a group of viruses, which causes disorders ranging from common cold to more middle east respiratory syndrome (MERS) and severe diseases like SARS [3]–[6]. Transmission of viruses takes place among both human beings and animals. For instance, SARS is transferred from civet cats to humans [7], [8]. This deadliest disease has infected 30 million people and more than 1 million people are killed around the globe [9]–[15]. Social distancing is used to curb the spread of this pandemic in the affected areas [1], [9], [16], [17]. Several countries have either opted for full or partial lockdown mechanisms [18]–[20]. Large gatherings, congregations, ceremonies, hotels, shopping malls, mosques, churches, synagogue, temples and other gathering platforms are banned for specific period of time [2], [18], [21]. The lockdown has affected every sector of society from the economy of developing to the developed countries, some of which have been collapsed already [22]–[29]. COVID-19 crisis has infact hampered the underdeveloped countries [7], [9], [30], [31]. Before the mass scale availability of the vaccine, social distancing and lockdown in present situation are the only available options to limit the menace of COVID-19.

With the emergence of COVID-19, it has been spread in many as 25 regions across the globe. In order to curb the virus, countries have entered into the race of COVID-19 vaccine [22], [32]–[34]. Availability of COVID-19 vaccine

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to mass is the hardest challenge faced by the governments [35]–[37]. Various studies of COVID-19 vaccines are aiming the diverse essential proteins, as a result most of these studies terminated soon after the pandemic of SARS and MARS [3], [38]. According to WHO, there are more than 100 candidates who are working on vaccine of COVID-19, most of candidates' samples are under trial [38], [39] and some of them has already been approved for emergency use. In this regard, WHO is also working with scientist, business giants, and global health organizations [40]–[42]. Most of the candidates of COVID-19 vaccine are under clinical trial phase. In order to limit the life threats, there is dire need to control the spread. Social distancing and self-isolation are best possible solutions to curb the COVID-19 spread [4], [22], [43]–[48]. Unprecedented pathway has engaged in examination and expansion by the global community for the development of effective vaccine. The research is mostly focused on the development of smart applications, which can minimize the effect of pandemic [39], [49]. COVID-19 is not the first nor the last pandemic. Technology can play a significant role to curb the outbreak of such pandemic by tracing and tracking of affected patients using technologies like contact tracking, cellular networks, voice over IP (VOIP), global positioning system (GPS), and beyond.

Call data record (CDR) based tracking of COVID-19 patients can help the health organizations to combat the spread of COVID-19 [50], [51]. Smart contact tracking identifies a person who is effected by the virus, who has to be quarantined for a period of 5 days followed by strict mask use for an additional 5 days [38]. This process basically evaluates the location and social connections of the exposed person. Data from GPS can detect prospective hot spots and specify the path traversed by COVID-19 patients [39]. Another potential candidate for tracking COVID-19 patients is based on contact tracing. Contact tracing follows proximity tracking. Bluetooth is mostly used in contact tracing for proximity tracking to record and measure the spatial contiguity among exposed persons [40], [52]–[54]. In case the suspected person is tested positive for the virus, spontaneously alert is directed to those who have been in the proximity of the exposed person for a certain time period [53]. The relevant information from health authorities may be provided as part of contact data record applications like suggestion for testing, suggestion for self-quarantine, near location of testing centers, or diet to follow [10], [22]. The extensive usage of applications such as contact tracing applications is the innovative solution to combat the pandemic and at first sight it might appear as a tempting and novel solution [8], [35], [53]. The basic purpose is to embolden the exposed individual to isolate themselves from others and pursue test and suitable treatment. As COVID-19 is individual to individual transmissible virus by the respirational drops at the time when an exposed person sneeze, cough or talk, the location of the mobile has been tracked, which is accommodating to recognize the potentially exposed person. This research paper provides a comprehensive information about tracking systems, which depends upon cellular networks based tracking system, cyber based tracking system, low range wireless tracking system, satellite based tracking system and hybrid technologies based tracking system as shown in Fig. 1. Moreover, this paper also highlighted the limitations of each model.

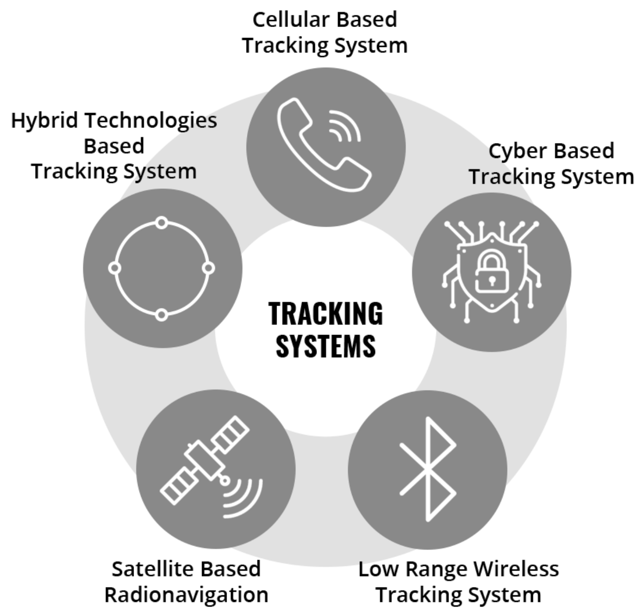

Fig. 1. Different types of tracking systems.

Rest of the paper comprehensively discusses various tracking systems to track COVID-19 patients along with their methodologies, case studies and limitations. Section II presents the tracking system based on cellular technologies. Tracking system based on cyber technology is discussed in Section III. Section IV covers tracking system based on low range wireless technologies. Section V presents the tracking system based on satellite radio navigation. Section VI presents the tracking system based on hybrid technologies. Section VII covers the discussion and future directions followed by conclusive remarks in Section VIII.

II. Cellular Based Tracking System

During pandemic for large scale observing, CDR data from the communication network base station, delivers admirable spatial pattern, which imitates urban life, temporal dynamics and it could hypothetically become an innovative way to excerpt or recognize as less apparent problems. CDR is basically a record keeper or file, which is retained through operators of mobile phone or telephone. The log file consists of extent of a call at a specific time, source and destination number, type of call, international mobile equipment identity (IMEI), call site aspect, and longitude/latitude of the base transceiver's station. Mostly law enforcement agencies around the globe use this to detect and trace the criminals [55]–[57]. Nowadays this technique is intended to detect the COVID-19 patients [50]. However, while using different techniques, users' privacy is a biggest concern nowadays from individual to country level. Privacy can be intact if the technique used in [50] is applied as the mechanism keeps the privacy concern as a top priority. It identifies the supposed cases over the call record of an exposed person and the particular path is followed by that person. Developed as well as under developed

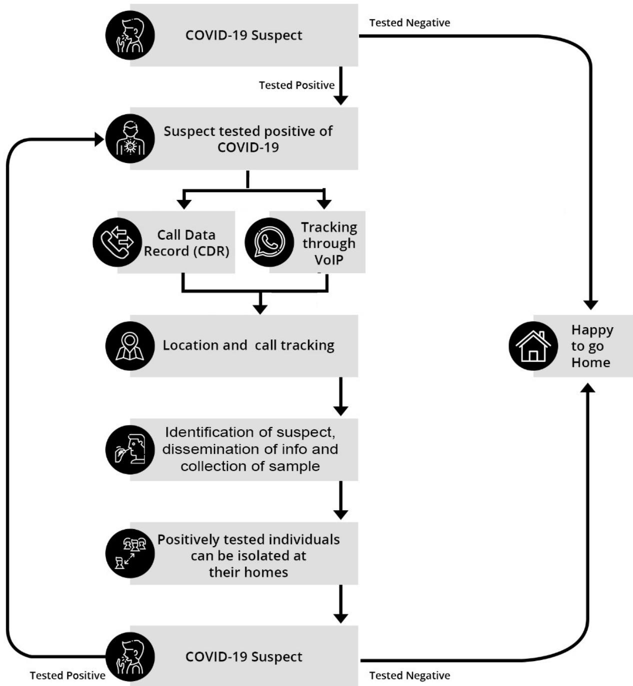

Fig. 2. Tracking system based on cellular and cyber technology.

countries are adopting the tracking system based on CDR to combat the pandemic of COVID-19. Initially, one has to perform CDR analysis (CDRA) on every individual who has recently travelled from abroad and can be a potential source of virus spread to others. In case, a person is found positive, the health regulatory authorities should inform the concerned government department for CDR analysis on a subject's active SIM with the permission of the suspected patient. The concerned department sends security alerts to all those people who were in contact with the suspected patient. After the person is confirmed with COVID-19, ambulance service is provided to the exposed person and get sample for corona virus. The suspected person is advised to follow quarantine and remain isolated till final test. As the test comes positive, the person is admitted to hospital for proper treatment and testing of family members and vicinity is cordoned off by the health regulatory authorities [50]. A complete flowchart of the tracking system based on CDR analysis is shown in Fig. 2. The overall execution of this model is explained in [50] and [51].

A. Limitations of CDRA

Some of the major limitations of CDR based tracking system are listed in this section.

1) Meet Without Call: It is not always possible that we meet after a call, we can meet with anyone without having a call. We are not sure whether the affected person is not aware about the infection, or the affected person is in public place. We spontaneously meet with the person without having a call. This issue cannot be handled by CDR. It is one of limiting factors in CDRA.

2) Call Made Through VOIP: Nowadays, most of people use social media applications, which provide instant messaging, audio and video call, virtual conferences, virtual ceremonies and virtual meetings within minimum cost [19]. It offers economic competence to users. There are many such applications like WhatsApp, WeChat, Skype, Line etc [23]. Since these apps are not registered in CDR log, therefore, it is not possible to track such calls using CDR analysis.

3) Approximate Sectored Location: One way to increase the capacity of a cellular network to make up for the increasing number of subscribers is to replace the omni-directional antenna at the base station with a number of directional antennas. This method is called cell sectoring. Cell sectoring is usually done by the operators due to increase in number of subscribers. One of the main limitations in the cellular based tracking system is to find the approximate sectored location.

4) Time Consumed in CDR Analysis: Another obvious limitation is the time taken to analyze the CDR of a patient. This will grow exponentially if the number of patients increases.

III. Cyber Based Tracking System Methodology

VOIP has largely increased in recent years thereby replacing the cellular services. Since record of the newly available study, the tendency par takes progress further than the general practice of the Internet and nowadays concentrating additional use of social and electronic media. Meanwhile from public, private and individual sectors calls made on VOIP remain unregistered in the log of CDR, as a result, it is not conceivable to track these type of cases by using CDR analysis. If a person corona test comes positive then he/she will be asked to handover the VOIP log to the concerned government department for further analysis. The VOIP log is converted into the format given in Table I. A complete working of this model is shown in Fig. 2. The overall execution of this model is explained in [50] and [51]. Moreover, number of papers have utilized Twitter data and successfully show that it is helpful in the context of contact tracing [58]–[61].

A. Limitations

This section highlights the limitations of tracking system based on VOIP log analysis.

1) Meet Without Call: Most of the times we meet with a person without making a call, in other words, we directly visit them. In such scenario, the mentioned model is unable to track the COVID-19 patients.

2) Call Made on Cellular Network: This tracking system fails to track if the call is made through a cellular network.

3) Time Consumed in VOIP Call Log Analysis: Another obvious limitation is the time taken to analyze the VOIP calls log of a patient. This will grow exponentially if the number of patients increases.

IV. Contact Tracing

Exposure notification system (ENS) is a collective effort of Google and Apple to help the health and government sectors to combat the pandemic of corona virus through contact tracing.

TABLE I
RELEVANT INFORMATION CONTAINED IN PATIENT VOIP CALLS LOG

Date & Time	A party	B party	Call Type	Call Duration (mins)
08/01/2020 11:15:11	1234567890	12121212121	Call Outgoing	14.03
08/01/2020 13:12:11	1234567890	13131313131	Call Incoming	14.23
08/01/2020 15:30:24	1234567890	14141414141	Call Outgoing	4.45
09/01/2020 13:34:44	1234567890	15151515151	Call Outgoing	1.03
09/01/2020 20:13:13	1234567890	16161616161	Call Incoming	2.11
09/01/2020 22:12:12	1234567890	17171717171	Call Outgoing	3.33
10/01/2020 15:12:24	1234567890	18181818181	Call Outgoing	4.22
10/01/2020 16:23:24	1234567890	19191919191	Call Incoming	3.32
11/01/2020 13:14:22	1234567890	12121212121	Call Incoming	5.34
12/01/2020 23:24:55	1234567890	15151515151	Call Incoming	13.23
13/01/2020 17:18:34	1234567890	17171717171	Call Outgoing	12.13
13/01/2020 19:12:24	1234567890	14141414141	Call Incoming	12.53
15/01/2020 12:12:42	1234567890	12121212121	Call Outgoing	4.33
16/01/2020 13:12:15	1234567890	16161616161	Call Outgoing	2.43
20/01/2020 11:33:24	1234567890	19191919191	Call Outgoing	1.32

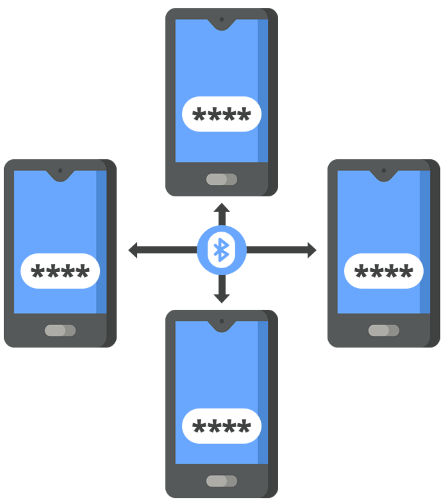

Fig. 3. Connectivity through bluetooth.

Contact tracing based on ENS informs the users of possible exposure to confirmed cases of COVID-19. Contact tracing generates random ID for the device in use. The random ID ensures the privacy of a user. Users own phone and the phones nearby them work in the background to exchange these privacy preserving random IDs through Bluetooth as shown in Fig. 3. All the random IDs will be checked by the phone intermittently connected with an exposed person of COVID-19 against his/her log. If these IDs are matched, the user will receive a COVID-19 exposure notification, having further directives from the concerned department about quarantine procedures. It does not track the location as it uses Bluetooth, which can detect at a time when two devices are near each other without revealing the identity of a device or user. Even the Google or Apple can't identify the identity. The overall execution of this model is explained in [50] and [51].

A. Limitations of Contact Tracing

There are many limitations, which need to be considered, in order to combat the outbreak of COVID-19 with the help of contact tracking.

1) High Power Consumption: Most of the apps like contact tracing based on ENS require heavy power usage. These apps shattered out the battery for the utilization of high power. This drawback limits the usages of contact tracing.

2) Installation of App: In order to trace the COVID-19 patients through contact tracing the app must be installed. If the app is not installed then it is not possible to track COVID-19 patients through contact tracing. Since contact tracing works on Bluetooth connectivity, therefore, smart devices should have this feature. If this feature is missing then contact tracing system fails to track the patients.

3) Technology Awareness: Technology awareness is biggest issue in developing or underdeveloped counties. People ignore the usage of technology. In order to use such application, one must have to literate about usage of app, installations, and connectivity.

4) Privacy Concerns: In order to install apps based on ENS, permission is asked to turn "ON" the location to detect the nearby devices. All the end users are forced to turn on the location before using such apps. Since contact tracing and other tracking apps allow to access the user location, therefore, privacy is one of the main concerns of tracking based on contact tracing.

V. TRACKING SYSTEM BASED ON SATELLITE NAVIGATION

It is the merely completely functional system of global navigation satellite, which is made from 24 constellations of satellites. It conveys signal to the receiver of the GPS. It determines location, speed of the receiver, direction of object and provides multiple path of a single destination. In many applications, it provides accurate time reference for calamities like earthquake, natural disasters, and synchronization for telecommunication networks. It was established by United States department of defense for the purpose of military applications and for the security concerns. Law enforcement agencies use it for the purpose of incident mapping of crimes. The information of criminals is identified through hot spots, trends and patterns mostly. Technology giants are trying their best to come up with solution to curb the spread of COVID-19. GPS plays significant role in tracking the location of exposed

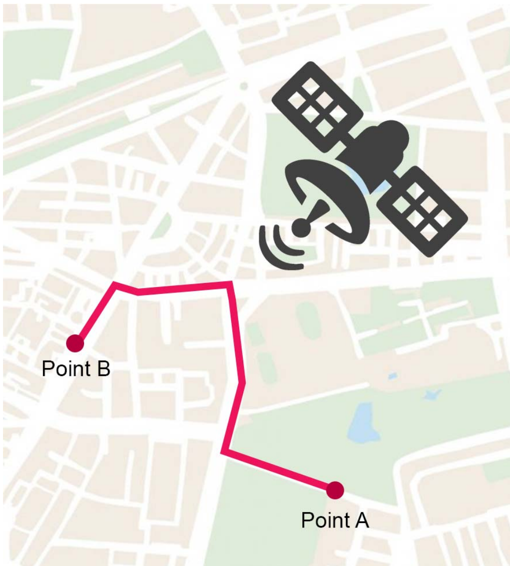

Fig. 4. GPS based tracking system.

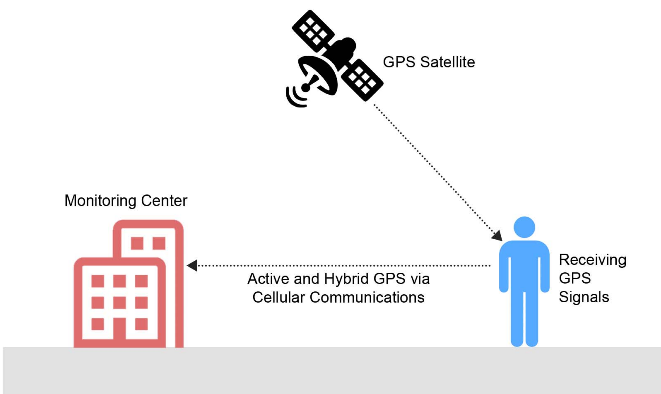

Fig. 5. Path traversed by COVID-19 patient.

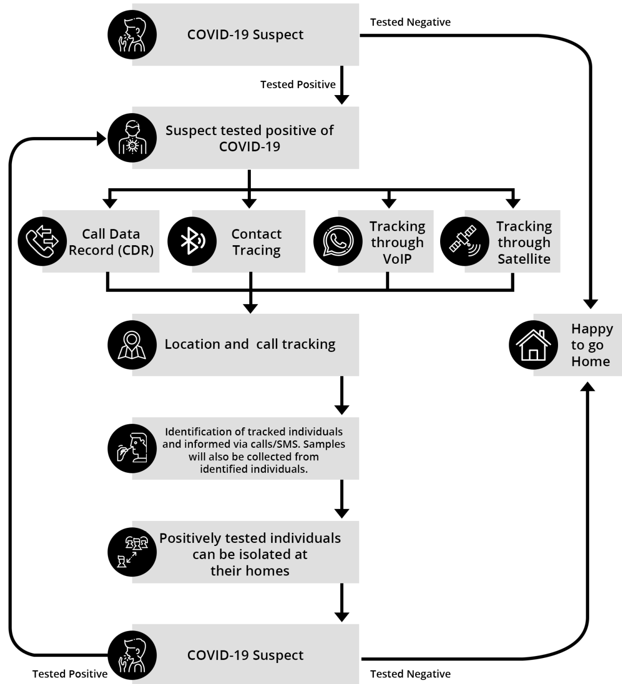

Fig. 6. Tracking system based on hybrid model.

persons of COVID-19 and can share the updated status of the exposed person(s) with the suspected person(s). Nowadays, most of the cell phones, identity cards and vehicles have GPS for the identification of locations, speed and time.

The exposed patients of COVID-19 have GPS placed in cell phones, vehicles, Identity card chips, or special device of GPS that can either be portable or fixed, which will help in identifying the location of exposed patient of COVID-19. GPS will provide the exact location of exposed patient. It will also track the movement of exposed person, which will monitor the route followed by the patient of COVID-19. Fig. 4 discusses how GPS technology operates by using different equipment like GPS receiver, charge unit, and mapping etc. for tracking it uses Global navigation satellite system (GNSS). GPS based tracking system is capable to preserve the path traversed by the COVID-19 patient as shown in Fig. 5.

Recent studies have revealed that the usage of the GPS for the purpose of tracking the location and time are now focusing on the usage of GPS for curbing the spread of COVID-19 by the use of GPS embedded in smart devices. A suspect/exposed person, contact with COVID-19, can tap the button and confirm as suspect of COVID-19. As a result, the government authorities will conduct the test in case of positive result, which will be sent to hospital and the location history will be checked by the government officials and send message to all the routes where an exposed person has routed and these path routes be marked as hot spots for no go area and will be disinfected. Health consultants send ambulance to the suspected patients where the exposed has routes' and will get sample or directly conduct test with testing kits of the COVID-19. Till the confirm reports declared about positive or negative result, the suspected person will be advised to stay at home for safety measures. In case it is positive, the suspected patient will be directed to some health institutions. The same process will be repeated for all those people where the suspected person has visited. More or less, GPS based devices collect the records, surrounded by the tracking system of GPS the aforementioned, which is recognized as "passive tracking". Some GPS based devices direct the data about the user to a central database or to the structure through a modem contained by the GPS method scheduled an unvarying foundation, which is determined by means of an active tracking. It receives microwave and satellite signals, in order to determine the location and track speed, time and movement of a person, which it uses for calculations. The overall execution of this model is explained in [50] and [51].

A. Limitations of GPS Based Tracking System

1) Imprecision: The device based on GPS mostly depends upon signals collect from at least 4 satellites. In case they connect with 3 satellites the location tracing will not be accurate. The problem can be created in case of buildings, walls, skyscrapers and trees, which can obstruct the accuracy. Harsh weather like storms can create inaccurate results.

TABLE II
LIST OF APPS AND ADOPTED TECHNOLOGIES BY DIFFERENT COUNTRIES

Countries	App Name	Technology	Voluntary	Open Source
Australia	COVIDSafe	Bluetooth	Yes	Yes
Austia	Stop Corona	Bluetooth, Google/Apple	Yes	Yes
Bahrain	BeAware	Bluetooth, Location	No	No
Belgium	Belgium's app	Bluetooth, Google/Apple	Yes	No
Bulgaria	ViruSafe	Location	Yes	Yes
Canada	COVID Alert	Bluetooth, Google/Apple	Yes	Yes
China	Chinese Health Code System	Location, Data Mining	No	No
Cyprus	CovTracer	Location, GPS	Yes	Yes
Czech	eRouska	Bluetooth	Yes	Yes
Denmark	Smittestop	Bluetooth, Google/Apple	Yes	Yes
Estonia	Estonia's App	Bluetooth, DP-3T, Google/Apple	Yes	No
Finland	Ketju	Bluetooth, DP-3T	Yes	Yes
Germany	Corona-Warn-App	Bluetooth, Google/Apple	Yes	Yes
Ghana	GH COVID-19 Tracker	Location	Yes	No
Gibraltar	Best Covid Gibraltar	TBD	No	No
Hungary	VirusRadar	Bluetooth	Yes	No
Iceland	Rakning C-19	Location	Yes	Yes
India	Aarogya Setu	Bluetooth, Location	No	Yes
Indonesia	PeduliLindungi	TBD	No	NO
Iran	Mask.ir	Location	Yes	No
Ireland	HSE Covid-19	Bluetooth, Google/Apple	Yes	No
Israel	HaMagen	Location	Yes	Yes
Italy	Immuni	Bluetooth, Google/Apple	Yes	Yes
Japan	COCOA	Google/Apple	Yes	No
Kuwait	Shlonik	Location	No	No
Malaysia	MyTrace	Bluetooth, Google/Apple	Yes	No
Mexico	CovidRadar	Bluetooth	Yes	No
New Zealand	NZ COVID Tracer	QR codes	Yes	No
North Macedonia	Stop Korona	Bluetooth	Yes	Yes
Northern Ireland	Northern Ireland's app	Bluetooth, Google/Apple	No	No
Norway	Smittestop	Bluetooth, Location	Yes	No
Philippines	StaySafe	Bluetooth	Yes	No
Poland	ProteGo	Bluetooth	Yes	Yes
Qatar	Ehteraz	Bluetooth, Location	No	No
Saudi Arabia	Tawakkalna	TBD	No	No
Singapore	Trace Together	Bluetooth, Blue Trace	Yes	Yes
Switzerland	Swiss contact-tracing App	Bluetooth, DP-3T, Google/Apple	Yes	No
Thailand	Mor Chana	Location, Bluetooth	Yes	No
Tunisia	E7mi	Bluetooth	No	No
Turkey	Hayat Eve Sigar	Bluetooth, Location	No	No
United Arab Emirates	TraceCovid	Bluetooth	No	No
United Kingdom	NHS COVID-19 App	Bluetooth, Google/Apple	Yes	Yes

2) Signal Failure: Core dependence of GPS can restrict it to work properly if the network signal drops or the battery of the device discharges completely. Most of the GPS devices are power hungry they depend on battery. In case the person battery gets dead during the half of journey, the rest of the location can't be tracked.

3) Privacy: Privacy is the biggest concern while using the GPS. GPS devices send data at real time without the permission of a user. Most of the people don't like to share their personal information and they don't allow the health and government officials to share their information. It restricts the usage of GPS for COVID-19 tracking.

VI. HYBRID TECHNOLOGIES BASED TRACKING SYSTEM

Another potential candidate for tracking system is based on hybrid technologies. It is recommended to use all of the above tracking systems in parallel to get the optimal results. This model uses all the above technologies for tracking COVID-19 patients as shown in Fig. 6. Since this model is based on combination of all of the above tracking systems, therefore, it holds the pros and cons of these models. Most of the countries whether developed or under developed have adopted digital contact solutions to support the manual tracing processes. These apps vary in the way contact tracing is performed. Some of the apps use GPS to track the users

TABLE III
COMPARISON OF DIFFERENT TRACKING SYSTEMS

Capabilities \ Technology used	CDR	VOIP	Contact Tracing	GPS	Hybrid
Track and Trace of COVID-19 patients having call history	✓	✗	✗	✗	✓
Track and Trace of COVID-19 patients without call history	✗	✗	✓	✗	✓
Track and Trace of COVID-19 patients having VOIP log	✗	✓	✗	✗	✓
Track and Trace of COVID-19 suspects having call history	✓	✗	✗	✗	✓
Track and Trace of COVID-19 suspects without call history	✗	✗	✓	✗	✓
Track and Trace of COVID-19 suspects having VOIP log	✗	✓	✗	✗	✓
Path alerts traversed by COVID-19 patients	✓	✗	✗	✓	✓
Privacy	✓	✓	✓	✗	✗

TABLE IV
COMPARISON OF PROPOSED MODEL

Tacking capabilities	[63]	[50]	[51]	Hybrid model
Tracing through call history	✗	✓	✓	✓
Tracing without call history	✓	✓	✓	✓
Tracing through VOIP calls	✗	✗	✓	✓
Tracing through call history (suspect)	✗	✓	✓	✓
Tracing without call history (suspect)	✓	✓	✓	✓
Tracing through social media calls (suspect)	✗	✗	✓	✓
Patient monitoring	✗	✓	✓	✓
Path traversed by COVID-19 patients	✗	✓	✓	✓
Real time path traversed by COVID-19 patients	✗	✗	✗	✓
Privacy	✓	✓	✓	✗

movements, while others use a more privacy-preserving design based on Bluetooth advertisements to register close contacts. Some governments have mandated the use of their apps, while others encourage voluntary adoption [62]. To build trust, many apps have their source code released for public scrutiny. Most of these international digital contact tracing apps are based on Bluetooth and GPS technology, while some also use QR. The list of apps used by 42 different countries with their technology adoption is presented in Table II.

VII. DISCUSSION AND OPEN RESEARCH ISSUES

This section discusses the capabilities of all existing tracking models and the futuristic approaches to make the tracking system more robust for minimizing the spread of COVID-19 like pandemics. There is increasing evidence that many patients with COVID-19 are asymptomatic or have only mild symptoms, but they are able to transmit the virus to others. There are difficulties in screening for asymptomatic infections, which makes it more difficult for national prevention and control of this pandemic. In fact all tracking systems work when the suspect is identified. In order to minimize the effect of asymptomatic patients, it is very important to increase the numbers of testing. The discussed models are capable to track and trace both symptomatic and asymptomatic patient once identified. Table III summaries the capabilities of different tracking systems and their comparison. From the Table III, it is clearly visible that hybrid model can easily track and trace COVID-19 patients in almost all scenarios. The only limitation of this model is the privacy issue. It is obvious that only using the CDR, we can track the patient if the call log is maintained. If the patient goes into crowd without making the call then CDR fails to track. However, in CDR, patient's privacy can be preserved. In case of VoIP technology, only VoIP call log is considered for tracking. In contact tracing, Bluetooth syncing is required to track the patient and it doesn't work if patient is out of the Bluetooth range. Similarly, GPS individually only uses to track the path of a suspect. Again, the privacy is big challenge for this technology.

Based on the above discussion, it is clear that the hybrid model is highly recommended to be adopted in all prospective pandemics in order to minimize the exposure and viral transmission. This will minimize the spread of virus in any sort of such pandemics. Table IV summaries the comparison of potential current tracking systems with respect to different capabilities. It is clearly visible from the Table III that hybrid tracking system is capable to track the COVID-19 patients in almost all of the scenarios. The only limitation of this model is the privacy concerns.

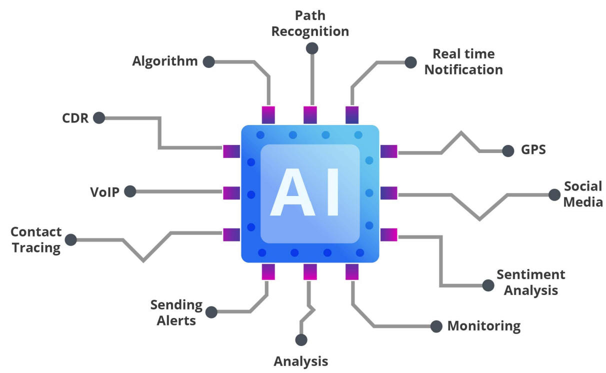

Fig. 7. AI based tracking system using big data analysis.

In future, this model can be automated by using Artificial Intelligence (AI) based approaches to make it more robust, efficient and time saving as shown in Fig. 7. The potential applications of AI and Big Data for the management of COVID-19 are summarized in Table V. AI and Big Data appear to have enormous potential for the management of COVID-19 and other emergencies, and their role is anticipated to increase in the future. AI and Big Data can be used to track the spread of the virus in real time, and plan and lift public health interventions, accordingly, monitor their effectiveness, repurpose old compounds and discover new drugs, as well as identify potential vaccine candidates and enhance the response of communities and territories to the ongoing pandemic [64]. These emerging approaches can be exploited together with classical surveillance: whilst the latter enables data analysis and interpretation, the former uncovers hidden trends and patterns, which can be used to build predictive models. Thanks to the latest advancements in the field of computational techniques and information and communication technologies (ICTs), artificial intelligence (AI) and Big Data can help handle the huge, unprecedented amount of data derived from public health surveillance, real-time epidemic outbreaks monitoring, trend now-casting/forecasting, regular situation briefing and updating from governmental institutions and organisms, and health resources utilization information.

A model is required to automate the entire tracking process of the patients in pandemic. This will fetch the data from different logs, such as CDR, VoIP logs, contact tracing log,

TABLE V
POSSIBLE APPLICATIONS OF ARTIFICIAL INTELLIGENCE AND BIG DATA

Time-Scale	Possible Application	Example
Short-term (weeks)	Rapid identification of an ongoing outbreak	AI can facilitate real-time data collection, risk-assessment and decision-making processes
Medium-term (months)	Identification of a potential therapeutic option	Identify already existing drugs/discovering new molecules
Long-term (decades)	Enhancing cities and favoring the development of healthy, smart, resilient cites	Design new standardized protocols for sharing data and information during emergencies

GPS log and social media logs. It will automatically analyze the data and extract hidden patterns. It will not only send notifications to suspects but also generate path followed by a suspect for general public to avoid further spread of a virus. AI based algorithms can be used to train the model from COVID-19 pandemic to any future pandemics. Such AI models can be capable to track and trace the affected one automatically rather than manually fetching and analyzing the data. It has been observed that the delay is one of the main limitations of existing tracking systems. It is humanly not possible to track and trace such a large numbers of patients. Such futuristic approaches will not only expedite the tracking process but also overcome the overall spread of such pandemics in future.

In addition to this, so far, the identification of hotspots is accomplished by the heath authorities through manual contact tracing, in which the contacts of the infected people had with other individuals during the incubation period of the pandemic are traced. The health authorities then contact the traced individuals and advise them to self-isolate. However, this approach is time consuming and resource demanding. Moreover, it is highly prone to errors, since people might not recall each person they may have met with or, even if they remember, they might not know them, e.g., contact with people in supermarket and local transport bus etc.

To cope with these issues, researchers have been focusing on digital contact tracing in which mainly the smartphones are used to efficiently keep track of the people who have been in contact with the infected individual. Many smartphones applications have been proposed such as Smittestop [65], VirusRadar [66], Immuni [67], Koronavilkku [68], Corona-Warn- App [69], SwissCovid [70], RadarCOVID [71], OstaniZdrav [71] etc.These applications mainly use the Bluetooth interface to collect the contact data and maintain a log of the contacts. The potentially infected individuals are promptly detected, and hotspots are identified.

The proposed applications in the literature are designed primarily on the proximity detection of nearby smartphones. However, these applications fail for scenarios where an individual encounters the virus on some surface. This situation is quite common in the local transport where individuals get on and off the bus frequently. For instance, if an infected person gets on the bus, a contact log will be created by the application. However, after some time when all the current passengers, whose log has already been maintained, gets off the bus, and a new person gets on the bus. The contact tracing chain of the infected individual is interrupted as shown in Figures 8 and 9. Similarly, all such public places are vulnerable to virus spread in the same fashion where one can easily get infected in the presence of virus on surface and in the absence of infected one as shown in Figure 10.

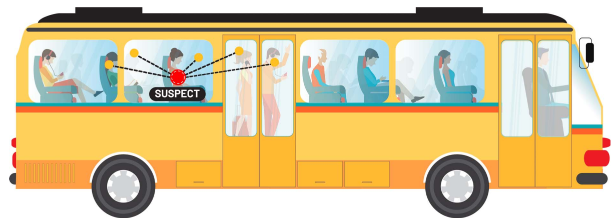

Fig. 8. Virus spread in local transportation.

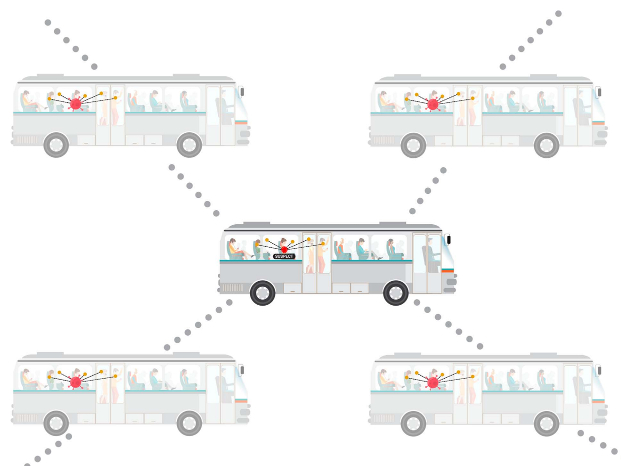

Fig. 9. Virus spread in the absence of infected.

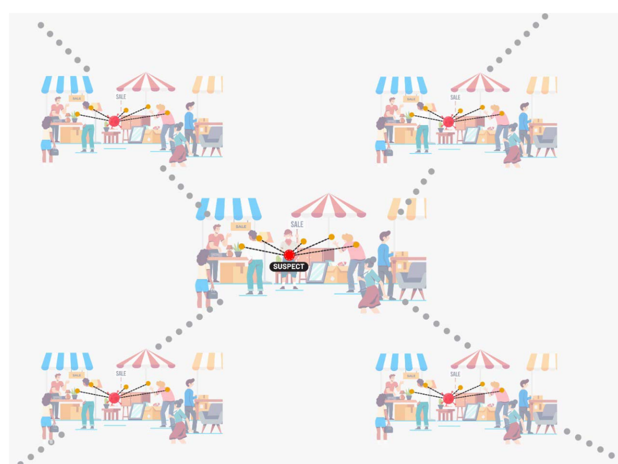

Fig. 10. Virus spread in public places.

VIII. Conclusion and Future Directions

COVID-19 has incurred huge loss to the lives of people throughout the world. Till now, around 2.5 Millions of lives have been lost in this pandemic. In current circumstances, different tracking and tracing mechanisms have been adopted to control or stop the spread of the virus. In order to track and trace patients in COVID-19 like pandemics, various tracking systems based on different technologies have been first introduced in this paper. The technologies include, cellular networks, cyber, satellite-based radio navigation and low range wireless technologies. The main aim of this paper was to conduct a comprehensive survey that can overview all such tracking systems, which have been used in minimizing the spread of COVID-19 like pandemics. In addition, the authors have proposed some futuristic approaches to track patients in pandemic based on AI based approaches and big data analytics. The futuristic models will fetch data from almost all those gadgets that maintain the logs of the affectees through social media, CDR, VOIP, GPS, and contact tracking etc. These proposed models are cost efficient and can be easily adopted not only in the developed but in the developing countries as well. The shortcomings of each tracking systems and suggested improvement to overcome such limitations have also been highlighted. This article also proposed potential research directions, challenges and next-generation tracking systems to minimize spread of prospective pandemics. In addition, authors have also highlighted the failure of contact tracing in local transportation, which become main source of virus spread.

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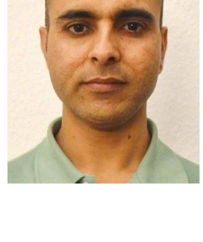

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