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Application of cognitive Internet of Medical Things for COVID-19 pandemic

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ABSTRACT

Background and aim: In the age of advanced digital technology, smart healthcare based on the Internet of Things (IoT) is gaining importance to deal with the current COVID-19 pandemic. In this paper, the novel application of cognitive radio (CR) based IoT specific for the medical domain referred to as Cognitive Internet of Medical Things (CIoMT) is explored to tackle the global challenge. This concept of CIoT is best suited to this pandemic as every person is to be connected and monitored through a massive network that requires efficient spectrum management.
Methods: An extensive literature survey is conducted in the Google Scholar, Scopus, PubMed, Research Gate, and IEEE Xplore databases using the terms "COVID-19" and "Cognitive IoT" or "Corona virus" and "IoMT". The latest data and inputs from official websites and reports are used for further investigation and analysis of the application areas.
Results: This review encompasses different novel applications of CIoMT for fighting the ongoing COVID-19 health crisis. The CR based dynamic spectrum allocation technique is the solution for accommodating a massive number of devices and a wide number of applications. The CIoMT platform enables real-time tracking, remote health monitoring, rapid diagnosis of the cases, contact tracking, clustering, screening, and surveillance thus, reducing the workload on the medical industry for prevention and control of the infection. The challenges and future research directions are also identified.
Conclusions: CIoMT is a promising technology for rapid diagnosis, dynamic monitoring and tracking, better treatment and control without spreading the virus to others.

1. Introduction

The entire world is affected by the novel coronavirus (SARS-CoV-2) pandemic that was reported from Wuhan, China, on December 31, 2019 now named Corona Virus Disease 2019 (COVID-19). It is the fastest spreading infectious virus which is resulting in a new menace to public health globally. Currently, the number of COVID-19 infection cases worldwide has reached 5,555,749 out of which 348,220 deaths are reported and the number of active cases stands at 2,875,734 affecting 213 countries [1]. These statistics are drastically rising every hour. In this global health emergency, currently the medical personnel and researchers are in search of new technologies to screen and control the spread of COVID- 19 pandemic. The quick monitoring of the viral infection is essential not only for healthcare professionals but also from a larger public health viewpoint to provide suitable patient isolation to avoid disease containment [2,3]. In this scenario, the advanced computational research like Internet-of-Things (IoT) and Artificial Intelligence (AI) is the current digital technologies that can be applied to tackle major clinical problems associated with COVID- 19 [4–6].

In this digital age of advanced technology, the recent developments in IoT in 5G telecommunication network, AI that includes machine learning algorithms (Random Forest, Naive Bayes, Decision Tree, Extreme Learning Machine, Reinforcement learning, Long Short term Memory Network, Convolutional Neural Network, etc.) and deep learning techniques, big-data analytics, cloud computing, Industry 4.0 and block-chain technology can provide long term solutions to tackle the COVID-19 pandemic [4–8]. These technologies can help to improve the diagnosis and treatment and also assist in the prevention of the spread of this disease. These

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inter-related technologies can assist in the collection of real-time data from persons at remote locations using IoT; processing, interpreting, forecasting and decision making using AI and big-data analytics; backing-up the data using cloud computing; and this is enhanced by blockchain technology for secure data networks as shown in Fig. 1. Cognitive Internet of Things (CIoT) is one such technology that enables each and every physical entity in the world to communicate and exchange information actively ensuring guaranteed Quality of Service (QoS) requirements. CIoT refers to the Cognitive Radio (CR) enabled IoT which supports machine-to-machine communication in an ever-increasing number of wireless devices network [4]. The CR based dynamic spectrum allocation technique is the solution for accommodating a massive number of devices and a wide number of applications. Cognitive Internet of Medical Things (CIoMT) is the class of CIoT specific for the medical industry which plays an important role in smart healthcare. The real-time physiological data of the patient such as the body temperature, blood pressure, heart rate, glucose level, EEG, ECG, oxygen level, etc. as well as the psychological data such as speech, expression, etc. are available to medical personnel remotely through IoMT [9]. The current review discusses the application of CIoT, more specifically the CIoMT for tackling the COVID-19 pandemic.

2. CIoT background

The Internet-of-Things (IoT) refers to a network of interconnected physical objects such as sensors, health monitoring devices, smart meters, home appliances, autonomous vehicles, etc. This massive connectivity enables objects to sense, process and communicate with each other, interact with the people automatically, and intelligently provide service to the users [10]. As the applications are increasing day-by-day as well as there is a tremendous rise in the number of interconnected wireless devices, the data traffic is estimated to reach 4394 EB by 2030(Source: ITU). To meet this ever-increasing bandwidth requirement, the cognitive radio-based IoT called Cognitive IoT (CIoT) is a promising technique for the efficient utilization of scarce spectrum [8]. The fundamental idea behind CIoT is to dynamically allocate radio channels for the exchange of information between the highly-dense interconnected objects. This concept of CIoT is best suited to this pandemic as every person is to be connected and monitored through a massive network. Also due to world-wide lockdown and restriction in movement and crowd, most of the activity goes online like e-commerce, e-learning, smart metering, e-surveillance, smart healthcare, and telemedicine services. These activities are possible via wireless communication and networking which consume bandwidth. The massive CIoT network transmits short packets by opportunistically searching the idle channels thus saving the bandwidth and utilizing the spectrum resource efficiently [8,9].

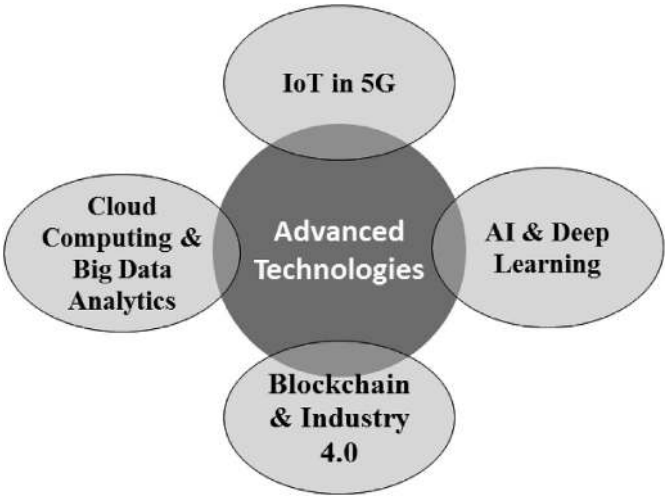

Fig. 1. Major advanced technologies to tackle coronavirus disease 2019 (COVID-19) pandemic. Abbreviations: Internet of Things in 5th Generation technology (IoT in 5G), Artificial Intelligence (AI).

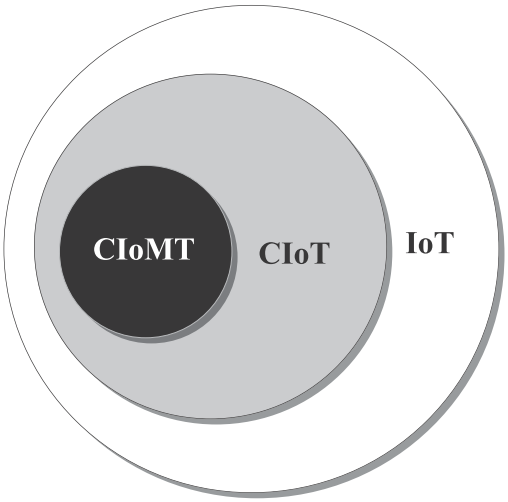

Fig. 2. Cognitive Internet of Medical Things (CIoMT) as a special case of Internet of Medical Things (IoT).

3. IoMT for COVID-19 pandemic

Presently the COVID-19 pandemic has become the hotspot of medical research. The new emerging technologies can be a panacea for this world-wide crisis. IoT and more particularly the IoMT can provide a solution to the challenges of detection, monitoring,

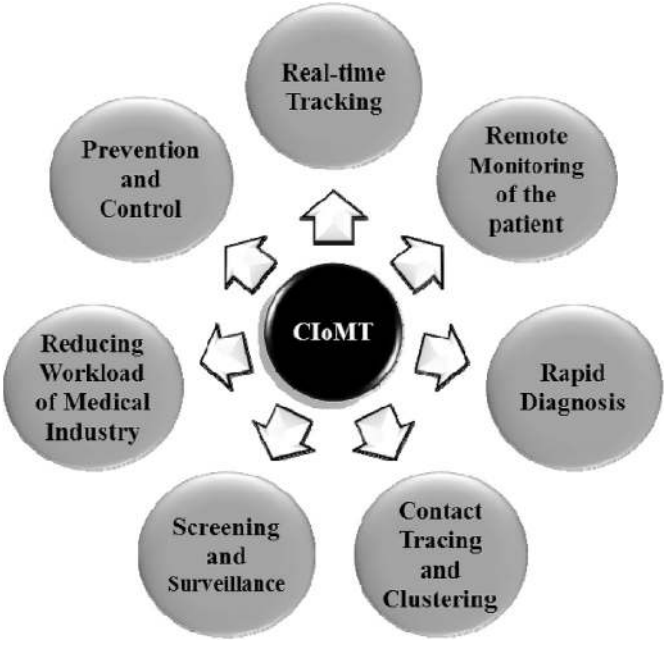

Fig. 3. Major application areas of Cognitive Internet of Medical Things (CIoMT) for tackling coronavirus disease 2019 (COVID-19).

contact tracing, and control of this disease [11]. IoMT refers to the interconnectedness of medical equipment, software applications, and data pertaining to the health-care industry. Smart health care monitoring is an emerging application of IoT which is best applicable during this COVID-19 pandemic. The CIoMT is a specialization of CIoT and further CIoT is an extension of conventional IoT whose relationships are shown in Fig. 2. The following sections encompass different novel applications of CIoMT for fighting the ongoing COVID-19 health crisis.

4. Applications of CIoMT

As noted above, several decades of research on smart healthcare has led to a progressively heightened application of CIoMT. Leaving behind the conventional treatment modalities, this technology gives opportunities to make significant advances in controlling COVID-19. The diagnosis, monitoring, tracking, and control of this crisis is carried out in real-time which includes daily new cases of the disease [9]. Since the entire population is affected, it is not easy to handle the situation by a few individuals, unless the live updates of data are available. The integration of sensory information, automatic processing, and communication through networks is enabled by CIoMT [12]. In this regard, CIoMT can be implicated in various major areas to tackle COVID-19 and has been illustrated in Fig. 3. In regards to COVID-19 crisis management, the application of IoMT is extensive in providing the on-line medical service for patients, getting proper health care, and test at home/quarantine center. Besides this, it can create a medical platform for the management of databases useful for government and health care services, as displayed in Fig. 4.

4.1. Real-time tracking

The real-time worldwide daily update in COVID-19 cases including the number of cured patients, number of deaths, and the number of active cases in various locations can be tracked using this technology. As a result the severity of the disease can be modeled and the disease activity can be predicted using AI for better decision making and preparedness for control by the health authorities and policymakers [6]. The government initiatives, health care precautionary measures, and treatment procedure updates can be available to each one connected to the CIoMT network [5,9,13].

4.2. Remote monitoring of the patient

As the COVID-19 pandemic is highly contagious, the doctors and

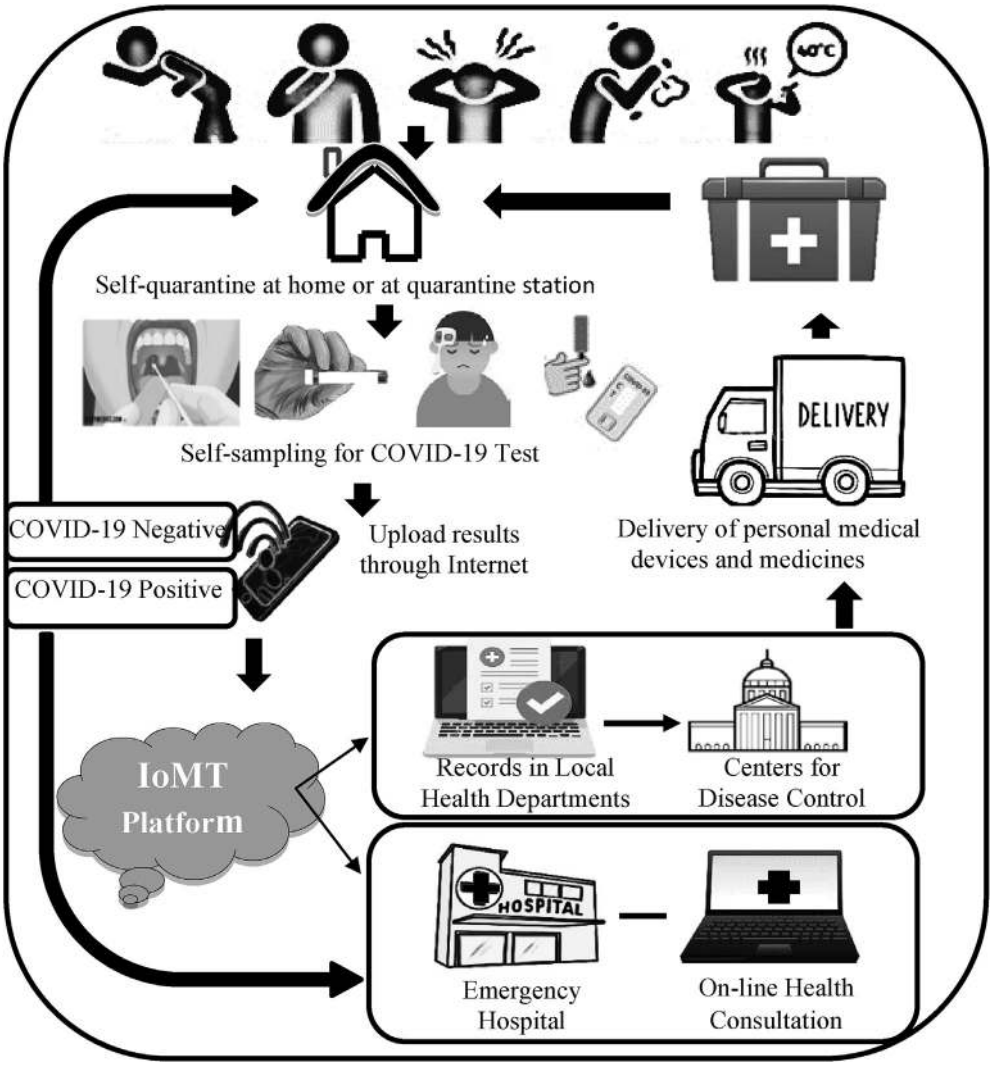

Fig. 4. Implication of Cognitive Internet of Medical Things (CIoMT) to connect with the healthcare information technology systems by using networking technologies for combating coronavirus disease 2019 (COVID-19).

healthcare workers are vulnerable to this disease during their period of service. The CIoMT helps the doctors to monitor the health condition of the patient remotely with fingertip medical data like Blood Pressure level, Glucose level, Heart rate, Electrocardiogram (ECG), Electroencephalogram (EEG), Electromyography (EMG), Pulse rate, Temperature, Breathing rate, etc. as illustrated in Fig. 5. This type of clinical parameter data acquisition is possible via wearable IoT sensors [5,14,15]. Since all the units of the COVID-19 hospitals are connected extensively through the internet, real-time communication of medical data is possible which saves time and effort. The application of CIoMT is useful especially for the elderly or patients having multiple ailments [9].

4.3. Rapid diagnosis

The migrants and suspected patients are quarantined even if they do not show any clinical symptoms, thus the rapid diagnosis of these cases is essential. CIoMT enables such persons with travel history to connect themselves to medical services for rapid diagnosis with minimal error through certain network applications. The lab technicians can remotely take the X-ray or computed tomography (CT) scan from the control room via the live streaming of the video images which can be further processed by AI-enabled visual sensors, thus taking less time to diagnose and confirm the case. This also enables contact-less and early detection of the virus [16].

4.4. Contact tracing and clustering

The contact tracing of the confirmed cases is highly essential to control the spread of the pandemic and this tedious work can be simplified if the location history of the COVID positive patient is readily available in the database which can be accessed by the healthcare authorities. The area-wise clustering and categorizing the regions as containment zones, buffer zone, red zone, orange zone, green zone, etc. can be updated quickly depending upon the number of confirmed cases via CIoMT. The location wise number of positive cases can be collected in real-time when the medical and health care units are interconnected via IoT. The government can access this data and alert for health checkups for the affected area and this can be done rapidly through AI framework [16,17]. The zone clustering also enables the public authorities to implement various lockdown and social distancing laws and orders.

4.5. Screening and surveillance

The thermal imaging-based facial recognition data at various entry points of airports, railway stations, hostels, etc. can be accessed via CIoMT by the public and healthcare authorities for screening and surveillance purposes [5,13]. This automatic surveillance of the suspected and positive cases can help to control the spread of the infection [9,17].

4.6. Reducing the workload of the medical industry

Starting from diagnosis, monitoring, and treatment the CIoMT assists the limited healthcare professionals to deal with a huge mass of the population. The CIoMT enables remote monitoring of the disease which further reduces the workload as discussed in sub-section 4.2. The lab technicians need not visit doorsteps for diagnosis as discussed in sub-section 4.3. The AI-infused with IoT sensory data further helps in modeling and forecasting of the infection [2,18,19]. Also, the hospitals can ensure timely door-step delivery of consultation via telemedicine and delivery of drugs by collaborating with blockchain companies.

4.7. Prevention and control

The spread of the virus can be controlled by the timely intervention of the healthcare and public authorities as well as by individual alertness [3]. The CIoMT enables one to know the positive case in the vicinity and to be alert by using certain apps (eg. Arogya Setu used in India). The clustering of geographical areas as discussed in sub-section 4.4 further restricts the disease spread [17].

5. Challenges and further research directions

Though the CIoMT can help to manage this global pandemic to a greater extent, there are certain challenges and loopholes which

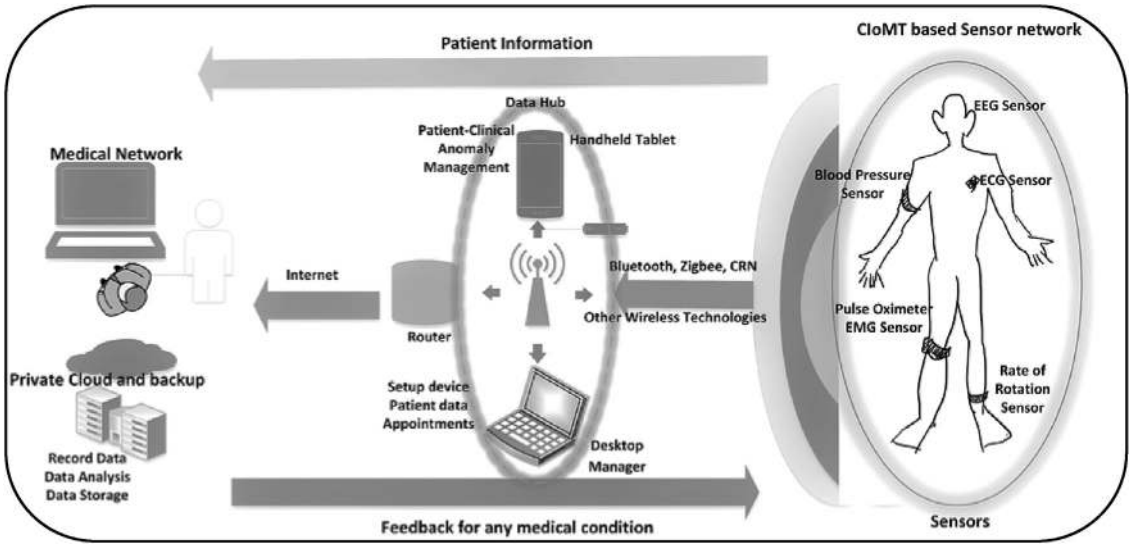

Fig. 5. CIoMT based remote monitoring of the COVID-19 patient. The IoT sensors such as Electroencephalogram (EEG) sensor, Electrocardiogram (ECG) sensor, Blood pressure sensor, Pulse Oximeter, Electromyography (EMG) sensor etc. helps in acquisition of real-time clinical parameters. The sensor data is collected into the data hub via Bluetooth, Zigbee, Cognitive Radio Network (CRN) or other wireless technologies. The patient information is transmitted to the medical network via the router through internet. The data is stored for severity assessment and predictive analysis and backed up in clouds. Finally the patient monitoring feedback is sent for effective treatment.

should be addressed. The privacy and security of the individual data is the prime concern which can be a future research problem [9]. The communication protocols and resilience to malicious attacks are further problems in a highly interconnected heterogeneous multimodal data network. The design and development of low power devices, energy efficiency, and reliable communication are the future interests of this study. The IoMT wearable sensors based on intelligent fabrics can be further researched upon. Further, for mental state assessment, emotion-aware abilities can be integrated into IoMT which can monitor the mental health of the patient during the COVID-19 pandemic and provide personalized therapy solutions [20]. Also the ethical issues in CIoMT lie as an open question.

6. Conclusion

This paper proposes the applicability of CIoMT disruptive technology for smart health care and to tackle the COVID-19 pandemic and introduces the major benefits and application areas. CIoMT is a promising technology for rapid diagnosis, dynamic monitoring and tracking, better treatment and control without spreading the virus to others. Further, the emergency strategies can be implemented cost-effectively, mitigating the stresses of the shortage of medical devices, maintaining a systematic database for modeling and predicting the disease activity for better decision making, preparedness, and online consultation.

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