Northumbria Research Link

Autonomous Transportation in Emergency Healthcare Services, Challenges and Future Work

Journal:	*IEEE Internet of Things Magazine*
Manuscript ID	IOTMAG-20-00076.R1
Topic or Series:	December 2020/IoT and the Environment
Date Submitted by the Author:	16-Oct-2020
Complete List of Authors:	Khalid, Muhammad; Northumbria University, Department of Computer and Information Sciences, Awais, Muhammad; University of Hull, Energy and Environment Institute Khan, Suleman; Northumbria University, Department of Computer and Information Sciences Singh, Nishant; University of Birmingham, School of Psychology Raza, Mohsin; Northumbria University, Department of Computer and Information Sciences Badar Malik, Qasim; KTH, School o Engineering Imran, Muhammad; King Saud University, Applied Computer Science
Key Words:	Fuel efficiency, internet of things (IoT), pollution, autonomous vehicles, artificial intelligence, autonomous transportation system, healthcare, deep neural network, deep reinforcement learning

Autonomous Transportation in Emergency Healthcare Services: Framework, Challenges and Future Work

Muhammad Khalid, Muhammad Awais, Nishant Singh, Suleman Khan, Mohsin Raza, Qasim Badar Malik, Muhammad Imran

***Abstract*—In pandemics like Covid-19, the use of autonomy and machine learning technologies are of high importance. Internet of things (IoT) enabled autonomous transportation system (ATS) envisions a fundamental change in the traditional transportation system. It aims to provide intelligent and automated transport of passengers, goods, and services with minimal human interference. While ATS targets broad spectrum of transportation (Cars, trains, planes etc.), the focus of this paper will be limited to the use of vehicles and road infrastructure to support healthcare and related services. In this paper, we offer an IoT based ATS framework for emergency healthcare services using Autonomous Vehicles (AVs) and deep reinforcement learning (DRL). The DRL enables the framework to identify emergency situation smartly and helps AVs to take faster decision in providing emergency health aid and transportation services to patients. Using ATS and DRL for healthcare mobility services will also contribute towards minimizing energy consumption and environmental pollution. This paper also discusses current challenges and future works in using ATS for healthcare services.**

***Index Terms*—Fuel efficiency, internet of things (IoT), autonomous transportation systems, autonomous vehicle, pollution, artificial intelligence, healthcare, deep neural network, deep reinforcement learning**

I. Introduction

THE large number of vehicles and road users has resulted in severe transportation delays, lower fuel efficiency, safety risks and accidents in traditional transportation system. The current transportation system is highly vulnerable to high traffic density and cannot effectively manage the traffic load, especially in peak times. Limited road infrastructure and rapid increase in vehicles is also affecting the response time of emergency services such as ambulances, fire brigades and police. In addition, the increased traffic density is resulting in poor fuel efficiency and increased pollution. Therefore, it is necessary to use the road infrastructure more effectively to cope with the rising needs in overwhelmed transportation system [1]. The IoT based ATS aims to provide flexible, highly efficient, safer, and smarter means of transportation. It also tries to minimize the time commitment most of the employees' experience while commuting to their work locations, thus enabling them to be more productive in the time otherwise wasted in driving [2]. The ATS is not only limited to driverless cars, rather its scope goes far beyond. Besides the driverless vehicles with virtually no need of human driving, ATS also aims low accident rates, efficient use of road infrastructure, vehicle prioritization, signal free junctions, effective wait free junction crossings, better traffic diversion, intelligent road use management, traffic optimization, fuel efficiency, low pollution and traffic diversion.

The IoT enabled ATS brings a new age of transportation and thus offers viable applications in all field of life. ATS can help in diverse fields such as transportation of passengers, transportation of goods, garbage collection, grocery delivery, emergency services and rescue response. In healthcare sector, ATS can bring new era of rapid response and emergency services to vulnerable patients. More coordinated and prioritized ambulance services can be offered to vulnerable patients. It can also initiate traffic diversion to enable prioritized and signal free road access to facilitate critical patient, thus minimizing the response time significantly [3]. It also offers potential for notable improvement in fuel efficiency and pollution reduction. While the ATS offers some viable benefits in the conventional healthcare system, the outbreak of coronavirus (Covid-19) has significantly changed how the healthcare services operate. In this new rapidly changing world, the need of ATS can more strongly be felt especially considering the healthcare concerns [4].

In the ongoing health crisis of coronavirus (Covid-19), the healthcare infrastructure was significantly affected. The rapid rise in Covid-19 cases resulted in additional burden on the healthcare staff, medical practitioners, and qualified medical experts across the globe. Since Covid-19 proved to be highly contagious, its widespread could not be limited even by imposing strict social distancing rules, guidelines, and lockdown. This resulted in large number of reported cases every day, thus compromising the ability of the ambulances and their staff/drivers to cope with the overwhelming demands from both Covid-19 and other emergency patients. It also put the ambulance staff and drivers at risk of conceiving Covid-19 [5].

M. Khalid and S. Khan are with the Department of Computer and Information Sciences, Northumbria University, UK (email: m.khalid@northumbria.ac.uk, suleman.khan@northumbria.ac.uk,).

M. Awais and M. Raza are with the Department of Computer, Edgehill University, St Helens Rd, Ormskirk L39 4QP, UK (email: mawais@ieee.org, mohsinraza119@gmail.com).

N. Singh is with the School of Psychology, University of Birmingham, Birmingham, Birmingham, UK (email: nishant22jan@gmail.com).

Q.B. Malik is with the KTH Royal Institute of Technology, Sweden (email: qasimbadar@gmail.com.

M. Imran is with the College of Applied Computer Science, King Saud University, Riyadh, Saudi Arabia; (email: dr.m.imran@ieee.org).

In addition to this, another fundamental change in the way healthcare was operating was witnessed in dealing with patients in need of regular medication. Earlier, these patients collected medicines from the general practices (GPs) on regular basis. However, considering increased chances of conceiving coronavirus, these patients are currently home medicated, and their medicines are delivered to their homes [6]. This not only puts additional responsibility on delivery drivers but also makes them more vulnerable to catching the disease.

In such prevailing circumstances ATS can play a significant role by minimizing the exposure of the drivers and managing the overwhelming load witnessed by the emergency ambulance services and transportation services. To facilitate the ambulance services, ATS can offer prioritized access and make effective use of the available resources [7]. In addition, the overall response time for the emergency patients can be reduced by efficient route formation, traffic control measures and prioritized access. ATS can also be used to transport non-critical Covid-19 patients using taxi services without putting the drivers at risk. Another important application aspect of ATS could be the food and grocery delivery where it can eliminate the delivery driver and consumer exposure. The ATS can also offer more effective route formation to get more deliveries done in lesser time ensuring reduced fuel consumption and pollution [8].

effective delivery of medicine to home medicated without exposing patients or drivers to Covid-19. With intelligent route formation medicine can be delivered to higher number of patients thus, maintaining the deadline. Similarly, grocery and food delivery services can be better managed without endangering anyone and managing the immense demands and maintaining desired customer schedule. The functional blocks and applications of ATS in healthcare is presented in Figure 1.

ATS offers countless benefits, especially in times plagued with pandemics, however, the realization of ATS still faces many challenges. While there are several preliminary and stand-alone solutions for automating transportation, yet consolidated and functional transportation paradigm is missing to fulfil the envisioned scope of ATS. The upcoming sections highlight the potential of ATS, main challenges, and its prospects.

II. Impact of Autonomous Transportation in Healthcare Services

Barriers in transportation have often been categorized as barriers to healthcare access. Delayed transportation can easily lead to appoints being missed, healthcare being delayed, and above all, in a state of emergency, putting lives at risk. These can easily lead to poor healthcare management. The impact of transportation on healthcare has been reported to be as high as 67% in a sampled population. Patients with chronic diseases

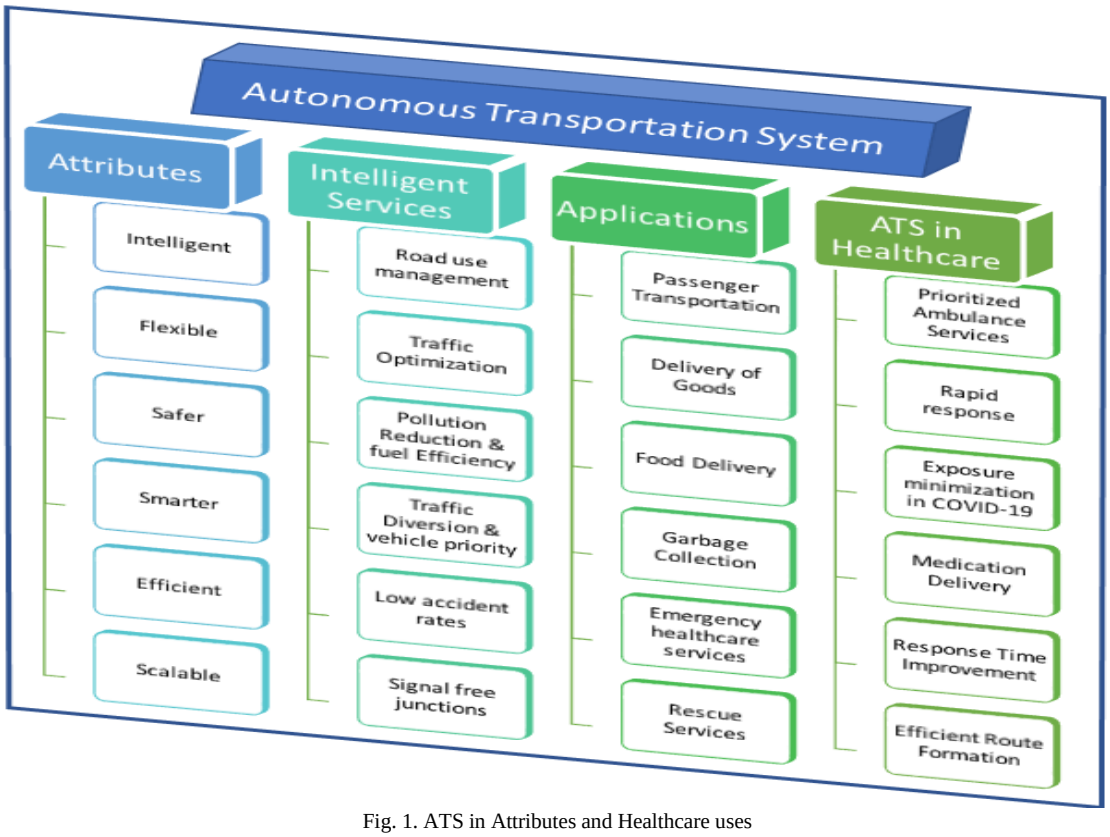

Fig. 1. ATS in Attributes and Healthcare uses

Use of ATS amid pandemics such as Covid-19 can offer improved emergency and healthcare services by limiting exposure, improving response time, offering better management of patient pick-up and drop off and facilitating more patients with same number of ambulances. It also allows need visits from clinicians and healthcare workers, access to medications and there may be changes to the plan of their treatment that need to be addressed within a specified time. It is extremely important to understand the relationship between transportation barriers and health to understand its impact on

life-saving decisions [9]. There is a wide gap between the transportation facilities expected from ATS and the available services. This has proved to have a large impact on the outreach of medical facilities that is directly or indirectly linked to the demographics of the patients.

A. Geographical and Demographic Impact

The geographical locations affect the modes of transportation being used and is very different for rural and urban locations. The options of transit, its cost and availability and the distance to the nearest healthcare facility are all critical factors in providing an effective means of transportation for a fast and reliable health assistance. The rural patients face a greater transportation difficulty, and this hinders their early access to the healthcare facilities when compared to their urban counterparts. The burden of travel is higher in the rural areas in comparison to urban facilities. There are longer driving distances for to reach the nearest hospital or the healthcare facility for the people living in the remote areas [10]. Traffic jams on their way is a prime hindrance in providing an optimal reach time. Traffic jams also cause high pollution which eventually lead to more health issues. This is where the ATS can provide a very good solution by means of connected vehicles. This will allow a better traffic management. With connected vehicles the emergency situations can be relayed easily through the traffic and the emergency vehicle can be prioritized more effectively. In addition, with well-coordinated traffic flow, the fuel efficiency can be improved while reducing the overall pollution.

B. Travelling Forward with Autonomous Transportation System

The evolution of the connected vehicles technology and the ATS will have a great impact on the emergency and the healthcare facilities. This has the potential to change the way of working of the medical response teams and organizations. Using IoT [14] and the networking of data through the cloud-based technology that share millions of data entities and elements will coordinate the movement of vehicles. The speed and accuracy of the resource selection is the key component of any emergency healthcare operation [11]. The ATS will provide a real-time platform for the integration of the audio and visual inputs from the resource sensors. The use of collected audio and video is a great resource for quality improvement, primarily utilized as a benefit for safety [12]. The cameras in ambulances capture the roadway in front and back of the vehicle. The data via these cameras are transferred and collected through wireless roadside units. Having a connected system throughout the roadway will facilitate a faster data and reliable data transfer time helping in a real-time video transfer. Remote guidance and operation control can be effectively carried out with the use of this connected technology. The limitation of the existing systems with the emergency vehicles in the presence of multiple emitters and traffic control units and there is a void created by the lack of all sharing a common activation protocol. Sensors, transmitters, and relays are essential components of the modern emergency healthcare vehicles that help in managing the climate control, geo-tracking, engine control wireless transmission of data etc.

One of the key components of healthcare vehicles is to provide cardiac care. “Time is muscle” and can be prevented with rapid

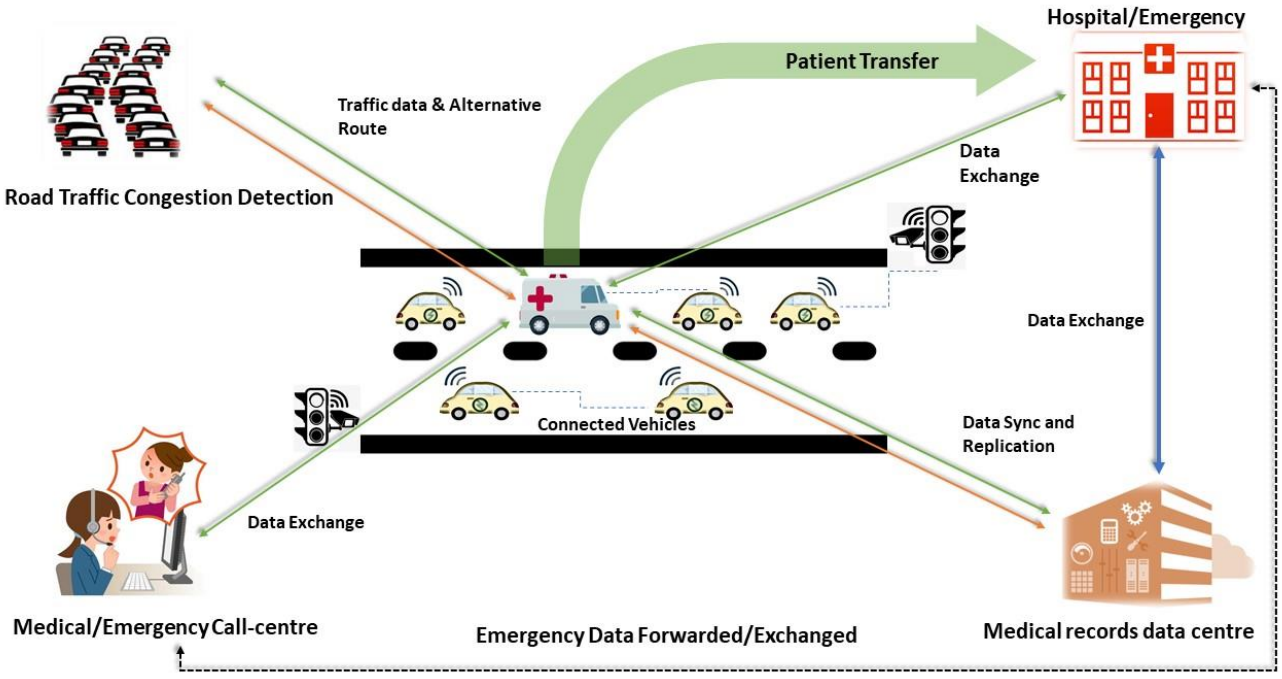

Fig. 2. ATS in Healthcare Services

recognition of such a cardiac blockage. With the advancement of IoT the paramedics and health care workers on site are able to send a 12-lead ECG signal from the site of emergency to the cardiac care centre in real-time, preparing the medical response team in the hospital even while the patient is being transported. There are more situations that can be handled well and be lifesaving by combining the pieces of information from different devices and sensors. This can be done very well bringing IoT, ATS and connected vehicle technologies together. ATS has provisions that has focus on quality and efficiency. A combination of short-range communication system and IoT will in the very near future make use of vehicle-to-vehicle and vehicle-to-infrastructure technologies for a better intelligent medical and patient transportation solution, as depicted in Figure 2. This will enable the medical response to be efficient, timely, fuel saving and will save more lives with a much less economic loss and contribution to pollution [13].

III. IoT Enabled Autonomous Transportation Framework for Healthcare Services

This section proposes a DRL based ATS for emergency healthcare services through an IoT framework. The proposed framework is capable of providing quick health services to patient using ATS. The ATS is fully dependent on DRL and IoT infrastructure. The DRL consists of agent, environment, actions, states and rewards. The agent, which is an ambulance in this scenario takes certain action in the environment (a city in scenario). Against every action, agent moves from one state to another state and receives certain reward. The goal of the agent in DRL is to maximize accumulative reward.

The goal of designing this framework is to enhance decision making parameters in emergency transportation. Due to the fact that transportation is emerging and moving towards autonomy, it is important to utilize these services in healthcare. ATS will help healthcare industry to be more prepared than ever before for health emergencies and pandemics like Covid-19. The ATS using DRL will enable healthcare services to be easily available to vulnerable people.

In the presented scenario in Fig. 3, two main aspects are defined, communication and decision making. In Fig. 3, each of emergency AVs act as an agent in the city. Certain parameters will be defined by health professional to declare a situation as health emergency. Once a patient is identified as emergency, a help request will be sent to nearest communication point. The communication point will inform all the nearest ambulances and hospitals of potential emergency event. The decision-making part for an emergency vehicle depends of its previous experience and real time data from the environment. With extensive training, an agent will perform much better and take intelligent decisions. After confirming a potential emergency situation, a Global Aggregator (GA) will be responsible to assign task to emergency AVs. The GA will consider the overall city traffic and congestion rate in that specific area. The GA will also utilize the road infrastructure and predict near future situations. The aim is to minimize total trip time, fuel consumption and pollution while saving critical patients. Once a task is assigned, emergency AVs will move towards patient location. Using real time data and learning experience will help emergency AVs to take faster decision and achieve higher reward. The proposed ATS framework for emergency healthcare services will significantly improve response time and minimize energy consumption and environmental pollution. By automating mobility services in healthcare can significantly increase delivery of services and minimize overall burden on healthcare organizations.

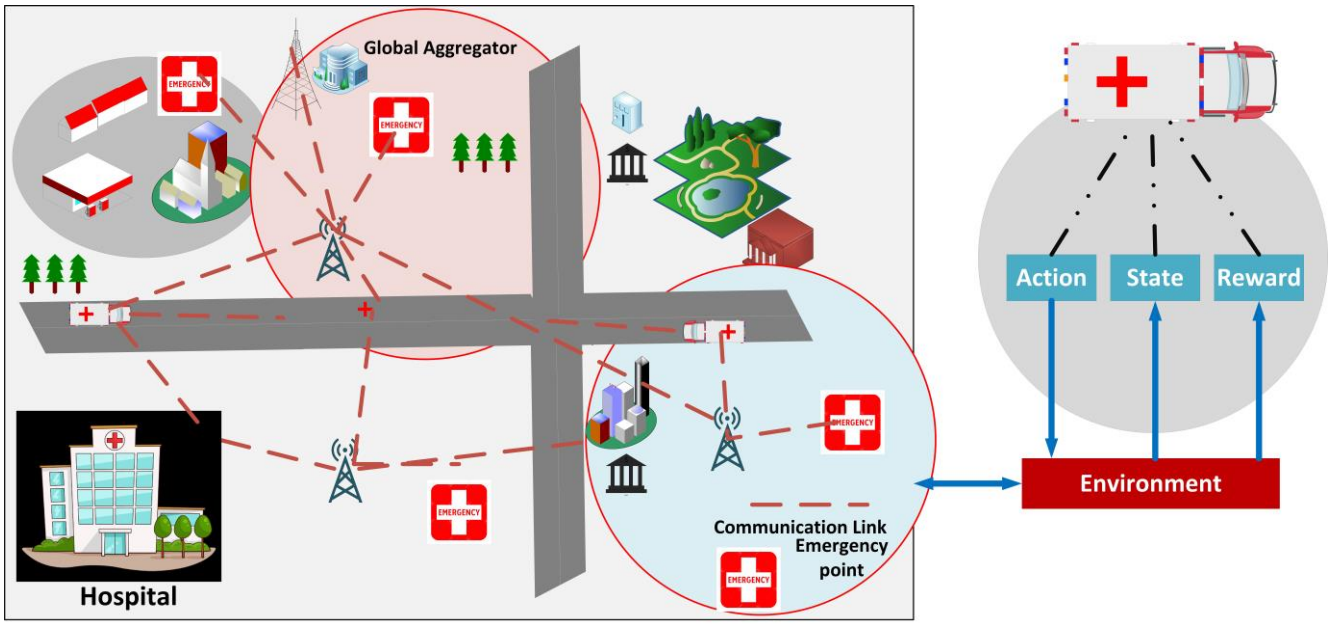

Fig. 3. IoT enabled ATS Framework for Emergency Healthcare Services empowered by DRL

IV. Challenges in ATS for Healthcare

This section presents novel challenges faced by the ATS industry in the Covid-19 pandemic, which are defined below and presented in Figure 4. The importance of challenges with its significance is described in subsections which will open ways for the researchers to work on. However, the discussion is

based on literature review and personal recommendation to highlight some areas which are of utmost importance to work on to overcome the problems faced in the pandemic.

A. *Medical Supplies*

The closure of the transportation industry has effect health supplies a lot which is crucial in this Covid-19 pandemic. Hospitals and surgeries are facing short of medical supplies due to items not reaching on time. Does the question arise that how ATS can help out in this problem? The role of ATS is vital as there is no direct involvement of humans. Many vendors can run AT vehicles to supply medical goods to different locations while transmitting low risk of virus. The vendors need to think about a quick solution to help out the healthcare industry to support the world in the fight against Covid-19.

B. *Drive-through*

During the COVID-19 pandemic, many countries in different cities have built drive through places for the public to provide sample tests for further investigation of the Covid-19. The people need to come and provide samples to the medical staff which needs to further send it to the laboratories for investigation. The AVs could be used to take these samples and send them to the laboratories with minimum human involvement. This could reduce the virus spread and will expertise the process quickly in diagnosing Covid-19 patients.

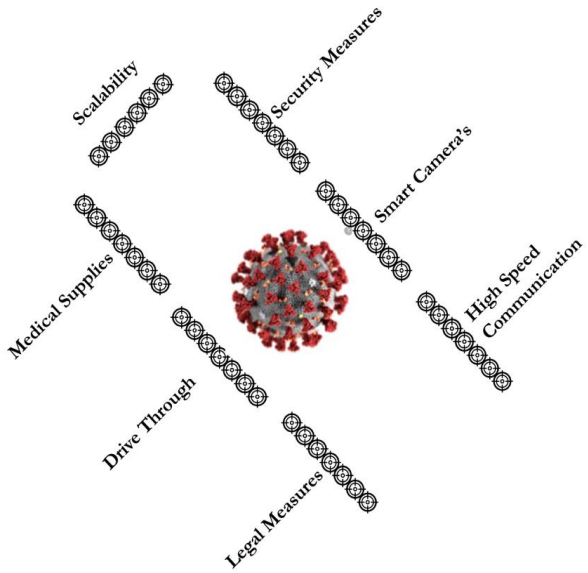

Figure 4: Key challenges faced by ATS in Healthcare services

C. *Smart Cameras*

The role of AVs could be from a different perspective in the Covid-19 as its main advantage is human-less drive. The smart cameras could be installed in the AVs which will capture the surroundings during the drive-in Covid-19. The AVs can capture human images which can be sent to the cloud storage where they can further process based on the impression, gestures, and other condition to identify possible Covid-19 patients. The vehicle could send the images, location, time, to the servers which on processing the data could inform the users to perform the medical test for confirming the results.

D. *High Speed Communication*

Sending information that is collected to the servers/peers is a vital stage for AVs. The information should reach on time, accurate, and unmodified to the destination. This could be done by demanding dedicated lines that should accommodate minimum interference. The entire world has started interacting online where they are using Internet connections. The usage of Internet connection has reduced the bandwidth available for AVs which might reduce its performance. The 5G would be a great booster for AVs however, there is still time available for it to be fully implemented and operable throughout the world.

E. *Security Measures*

The smooth operation of the AV is important to support the Covid-19 pandemic. One important factor is the security of AV itself. Any security breach could result in disasters that might damage the entire system. How AVs could protect from cyber-attacks as it needs to be connected with numerous vehicles, stations, servers, and other identities. There should be a security layer that enables AVs to protect them from any malicious contacts. Data send to different servers need to be protected from malicious exploitation and its integrity should be ensured.

F. *Scalability*

Scalability is quite a common issue with AV right from the beginning. Any vendor creates a vehicle that will work based on its feed data and environment. For instance, a vehicle build in china by a Chinese company will understand the local environment and measures which were embedded into the vehicles. Moreover, many AVs work on geo-specific rules which makes it difficult to expand to new cities, adopt new rules and behaviors. This could be the case in the Covid-19 pandemic as many AVs are built without consideration of the current situation. This could be a challenge for the AV industry that how they need to utilize existing built vehicles to provide support in this pandemic.

G. *Legal Measures*

Many countries have not had legal permits for users to run AVs on the roads. Some countries have proper legislation for AVs and have provided access to users. In this Covid-19 pandemic, almost every country is facing coronavirus, any supportive solution provided by AVs would be a challenge for the countries which don't have any rules or policy for AVs to be operating on the roads. For instance, what would be its speed, who will be responsible for an incident, what information would be collect and process, and much more? The legal aspect might be a great issue in some countries where (General Data Protection Regulation) GPDR has been fully implemented.

V. Future of ATS in Healthcare

The essence of AVs has become more evident amid Covid-19 since the contagious nature of such pandemics force individuals to minimize or avoid human to human contact for possible transmission. Despite, current legal and technical issues in transforming AVs into mobility services, AVs have got unpredicted uptick due to the potentials application these can provides in future pandemics. The future of AVs is highlighted in Figure 5, while further details are described in the following sub-sections.

Figure 4: Future of ATS in Healthcare

A. *Pick and drop to and from Healthcare Services*

The very basic aim of a transportation service is to provide pick and drop facility to individuals from one location to another. Such services will be the heart of future AVs; however, the major difference is that these AVs would offer contactless means of transportation allowing key workers, healthcare staff and patients towards their destination safely and securely without contributing toward the spread of pandemic. Since, human driver can become a potential source of contagion, AVs would significantly reduce such resources through contactless mobility service. Moreover, this will also reduce the chances of front-line workers getting infected with pandemic. This is a critical issue amid pandemic where thousands of healthcare workers are contaminated, significantly reducing the lifesaving workforce. These on-demand mobility services i.e. AVs (working only when required) will meet the high standards of efficiency along with career safety since these would not require special preparation requirements (e.g. driver's availability) with minimal on-board contagion risk due to driverless facility.

B. *Self-Isolation Equipped AVs*

The future AVs equipped with self-isolation measures through multiple isolated compartments will provide perfect isolation mean to individual passenger or a small group of passengers with similar health conditions. This will potentially reduce the chances of contaminating healthy groups from ill passengers. Moreover, such AVs equipped with cleaning and disinfecting equipment can maintain high standards of hygiene aboard which are keys precautionary measures to tackle such contagious and airborne infections alike Covid-19.

C. *Diagnosing patients aboard AVs*

The future AVs can potentially provide diagnostic of pandemic prior to reaching hospital. For instance, a person calling healthcare potential requiring urgent medical treatment with health symptoms of potentially infection of Covid-19. However, the healthcare staff is unaware of any of these symptoms. The diagnostic enabled AV when arrives to pick this person, will monitor patient's body temperature and coughing contactless and transmit the healthcare indicators in real-time to hospital care practice. The healthcare practice will then make informed decisions about the possible treatments the arriving patient require, without contaminating the healthcare workers in case the patient in already suffering from Covid-19.

D. *AVs to disinfect cities*

The future AVs can provide high hygiene standards across smart cities by effectively disinfecting the public areas, roads, parks, hospitals, residential amenities etc. Such AVs are already in practice in some areas to disinfect roads. However, these AVs require further developments in order to translate these to smart cities covering wide area.

E. *AVs to enforce social distancing*

Enforcing social distancing is vital in containing the pandemic and AVs in this regard can significantly assist the local authorities. Implementing social distancing on a nationwide scale is very critical yet difficult to implement due the limited staff and resources. The visual and voice enabled AVs can detect the mass gathering or even small gathering not practicing the social distancing. The visual and audio sensing can be interpreted automatically with the advent of AI and big-data [15] developing real-time decision support system updating the law enforcing agencies and policing authorities to identify individual violating social-distancing. Such AVs can be deployed in public places such as parks, outside hospitals, restaurants, roads, and around residential amenities. These DRL-powered AVs directly reduces the population through enhanced fuel efficiency.

F. *AVs for contactless delivery*

Regardless of the severity of the pandemic, freight trucking is essential to keep the life moving. Embarking AV enabled trucking for delivering essentials is the future which can effectively help almost every industry. The delivery enabled AVs will be less contagious and effective since there would no human to human contagion and resource dependencies while moving the goods. The potential applications are 1) Movement of essential lifesaving medical supplies and personal protective equipment (PPE) from production sites to consumer locations such as hospitals, healthcare practices and pharmacies, 2) Transportation of food supplies from agriculture and production industries to supermarkets, 3) Delivering cleaning and hygiene supplies to distributors. Despite these pandemic related

deliveries, AVs will assist other manufacturing and supply chain industries at large by provide safe and secure mode of mobility service.

All the above-mentioned prospects of AVs will not only provide a reliable and on-demand secure means of transportation but also significantly enhance the cost effectiveness. The cost efficiency will occur in terms of requiring less staff, enhanced fuel efficiency due to reduction in unwanted travels and also significantly saving on PPE and medical supplies since driver/staff less AVs will only go to pick patients, thus not requiring any PPE aboard. The AV based on-demand mobility service will also significantly mitigate the environmental population currently occurring due to excessive and unwanted use of non-AV based transportation.

VI. Conclusion

The integration of DRL and ATS in emergency healthcare through IoT infrastructure will deliver effective and promising solutions in addition to improved fuel efficiency and reduced pollution. The DRL can enhance decision making and computational intelligence in ATS for healthcare. In this paper, we proposed an abstract level model for ATS in healthcare services. The use of autonomy helps to control the emergency situations in pandemics when less healthcare professionals are available to work. The DRL enhances the system by providing quick responses in transportation services. The DRL optimizes fuel efficiency and minimizes overall travel time and cost to emergency points and hospitals. The overall ATS framework aims to not only improve the efficiency of transportation related issues in health crisis (such as Covid-19) but also targets daily life limitations of conventional transportation systems, thus making transportation more efficient whether it is journey time, fuel consumption, air pollution, or vulnerability reduction. In future, we aim to extend this framework to a fully integrated and enhanced ATS solution for healthcare services in pandemics like Covid-19.

References

[1] H. Zhang, J. Li, B. Wen, Y. Xun and J. Liu, "Connecting intelligent things in smart hospitals using NB-IoT", *IEEE Internet Things J.*, vol. 5, no. 3, pp. 1550-1560, Jun. 2018.

[2] Riek, Laurel D. "Healthcare robotics." *Communications of the ACM*, 60, no. 11 (2017): 68-78.

[3] I. Bisio, C. Garibotto, F. Lavagetto, and A. Sciarrone, "When eHealth meets IoT: A smart wireless system for post-stroke home rehabilitation," *IEEE Wireless Commun.*, vol. 26, no. 6, pp. 24–29, 2019.

[4] C. S. Nandyala and H.-K. Kim, "From cloud to fog and IoT-based real-time U-Healthcare monitoring for smart homes and hospitals", *Int. J. Smart Home*, vol. 10, no. 2, pp. 187-196, 2016.

[5] Fischer, Gabriel Souto, Rodrigo da Rosa Righi, Gabriel de Oliveira Ramos, Cristiano André da Costa, and Joel JPC Rodrigues. "ElHealth: Using Internet of Things and data prediction for elastic management of human resources in smart hospitals." *Eng. Appl. Artificial Intelligence*, Vol. 87, 103285, 2020.

[6] Hongxu Zhu et al., "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, Sept. 2019.

[7] Tavakoli, Mahdi, Jay Carriere, and Ali Torabi. "Robotics, smart wearable technologies, and autonomous intelligent systems for healthcare during the COVID-19 pandemic: An analysis of the state of the art and future vision." Advanced Intelligent Systems (2020): 2000071.

[8] D. He, R. Ye, S. Chan, M. Guizani and Y. Xu, "Privacy in the Internet of things for smart healthcare", *IEEE Commun. Mag.*, vol. 56, pp. 38-44, Apr. 2018.

[9] S. Rani, S. H. Ahmed and S. C. Shah, "Smart health: a novel paradigm to control the chickungunya virus", *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 1306-1311, 2018.

[10] A. Alabdulatif, I. Khalil, A. R. M. Forkan and M. Atiquzzaman, "Real-time secure health surveillance for smarter health communities", *IEEE Communications Magazine*, 2018.

[11] Humayun, Mamoona, N. Z. Jhanjhi, Bushra Hamid, and Ghufran Ahmed. "Emerging Smart Logistics and Transportation Using IoT and Blockchain." *IEEE Internet of Things Magazine*, Vol. 3(2), 58-62, 2020.

[12] Rajasekaran M, Yassine A, Hossain MS, Alhamid MF, Guizani M. Autonomous monitoring in healthcare environment: Reward-based energy charging mechanism for IoMT wireless sensing nodes. Future Generation Computer Systems. 2019 Sep 1;98:565-76.

[13] L. Catarinucci et al., "An IoT-aware architecture for smart healthcare systems", *IEEE Internet Things J.*, vol. 2, no. 6, pp. 515-526, Dec. 2015.

[14] M. Awais, M. Raza, K. Ali, Z. Ali, M. Irfan, O. Chughtai, et al., "An Internet of Things based bed-egress alerting paradigm using wearable sensors in elderly care environment", *Sensors*, vol. 19, no. 11, pp. 2498, May 2019.

[15] M. Raza, M. Awais, W. Ellahi, N. Aslam, H. Nguyen and H. Le-Minh, "Diagnosis and monitoring of Alzheimer's patients using classical and deep learning techniques", *Expert Syst. Appl.*, vol. 136, pp. 353-364, Dec. 2019.

Muhammad Khalid received the M.S. degree in computer science from the Institute of Management Sciences, Peshawar, Pakistan. He is currently pursuing the Ph.D. degree with Northumbria University, Newcastle Upon Tyne, U.K. His research interests include EV charging and scheduling, the Internet of Things, wireless sensor networks, and autonomous valet parking.

Dr. Muhammad Awais is Senior Lecturer at Edge Hill University, UK. Previously, he worked as a Research Fellow: in Data Analytics and AI at University of Hull, UK and in Signal Processing and Machine Learning at University of Leeds, UK. His research interests are in signal processing, applied machine learning and deep learning to develop ICT based systems for Internet of things, Industry 4.0, biomedical and health care domain.

Dr Nishant Singh was awarded a PhD in Bio-Medical Technology, Birla Institute of Technology (BIT), India. Currently, he is a postdoc research fellow at the School of Psychology, University of Birmingham, UK. He worked as a Research Assistant at the Biomedical Instrumentation Laboratory, BIT, and at Middlesex University, UK.

SULEMAN KHAN received several Master programs, including the M.Sc. degree in computer science from the University of Peshawar, Pakistan, in 2006, and the M.S. degree in distributed systems from the Comsats Institute of Information Technology, Abbottabad, Pakistan, in 2011, and the Ph.D. degree (Hons.) from the Faculty of Computer Science and Information Technology, University of Malaya, Malaysia, in 2017.

Dr Mohsin Raza is Senior Lecturer at Edge Hill University, UK. Prior to this, he worked as lecturer (2018-19) at Northumbria University, a post-doctoral fellow (2018-19) at Middlesex University, UK, Junior lecturer (2010-12) and later as Lecturer (2012-15) in at Mohammad Ali Jinnah University, Pakistan, and Hardware Engineer (2009-10) at USS, Pakistan. His research interests include IoT, 5G, ITS, machine learning, Industry 4.0 and digital twins.

Muhammad Imran is an associate professor in the College of Applied Computer Science, King Saud University. His research interests include mobile and wireless networks, IoT, software-defined networking, cloud and edge computing, and information security. He has published several research papers in top journals. He serves as the Editor-in-Chief of EAI Transactions on Pervasive Health and Technology.