

The Survey of Self-driving Car Challenges in Smart City Infrastructures

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Abstract. The article provides an overview of the current situation of interaction between self-driving cars and a smart city. We will look at what successes have been achieved in the adaptation of autonomous vehicle in the context of smart urban mobility. Will speak about unmanned logistic corridors and autodata question. A small comparative analysis of various approaches for solving problems in this direction is given.

Keywords: self-driving cars · autonomous vehicle · smart cities

1 Introduction

This article is primarily aimed to give the reader an idea of what areas for research in the field of autonomous vehicles exist at the moment and how they connect with the smart city infrastructure. To a greater extent, the article deals with problems related to their technical development, and The issues of regulatory and ethical concerns are beyond the scope of the paper, since quite a lot of articles have already been submitted on this topic.

Before speaking about Vehicle-to-Everything communications and Big Data problems of self-driving cars let take a brief view on the connection of different concepts, related to self-driving and its infrastructure. The topics we will speak about in the next subsections shown on the Fig. 1.

1.1 Urban Mobility

Urban mobility refers to the movement of people and goods in urban areas. With the growing population and increasing urbanization, mobility has become a significant issue in cities. Some of the key features of urban mobility are:

Multimodal Transport: Urban mobility is not limited to a single mode of transportation. It involves different means of transport such as walking, cycling, public transport, and personal vehicles. A well-integrated multimodal transport system can improve the efficiency of urban mobility.

Accessibility: Urban mobility aims to provide convenient and easy accessibility to all parts of the city. This includes not only physical access but also ease of payment, information, and communication.

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O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14109, pp. 290–301, 2023.
https://doi.org/10.1007/978-3-031-37120-2_19

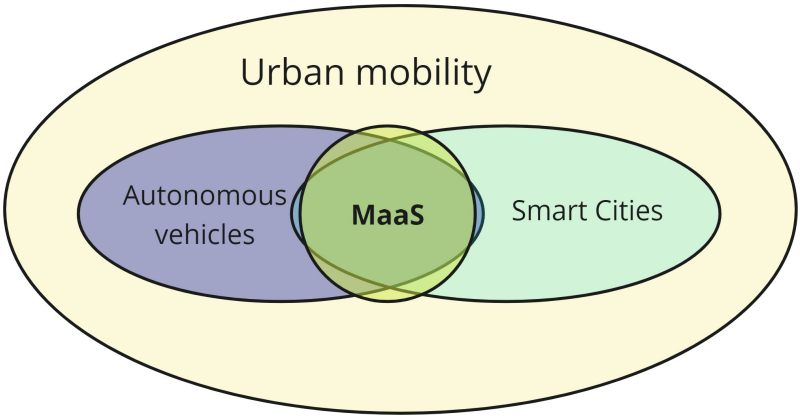

Fig. 1. Connection between Self-driving and Urban mobility

Safety: Urban mobility should ensure safety for all users, including pedestrians, cyclists, public transport users, and personal vehicle users. This includes implementing safety measures such as proper road markings, traffic signals, and pedestrian crossings.

Sustainability: Urban mobility needs to be sustainable to ensure the long-term well-being of the city and its residents. This includes reducing carbon emissions, promoting public transport, and encouraging active modes of transportation such as cycling and walking.

Intelligent Mobility: The use of technology in urban mobility can help improve efficiency and reduce congestion. Intelligent transport systems can provide real-time information about congestion, parking, and public transport schedules, enabling users to make informed decisions.

Overall, urban mobility is a complex and interconnected system that requires integrated planning and coordination to ensure efficient, safe, and sustainable transportation.

1.2 Smart City Infrastructures

Smart city infrastructures are the backbone of the modern cities that cater to the needs of the population in a smart way. The infrastructure consists of various technological interventions such as smart energy grids, water management systems, transportation management systems, and other smart services that make life in the city more sustainable and convenient. The smart city infrastructure is built on a framework of Internet of Things (IoT) devices, sensors, and data analytics.

Smart energy grids are the most crucial part of smart city infrastructures. They are designed to optimize the efficient use of energy by monitoring and controlling the energy usage in real-time. The energy grid collects data on energy usage patterns and uses this information to control and manage energy supply and demand. This ensures that the energy is distributed to where it is needed most and reduces the overall energy consumption.

Water management systems are also an essential part of smart city infrastructures. These systems use IoT devices and data analytics to monitor water usage and quality in real-time. This helps to reduce water loss due to leaks, and the systems can also be used to detect water quality issues and alert authorities.

Transportation management systems are also a vital part of smart city infrastructures. These systems help to reduce traffic congestion and improve public transportation services. Smart parking systems are used to optimize the supply and demand of parking spaces, while smart traffic lights improve the flow of traffic on roads.

Other smart services include waste management systems, which use IoT devices to monitor waste generation and collect data on the waste's composition. This helps to optimize waste collection and disposal and reduce the overall amount of waste generated by the city.

Overall, smart city infrastructures are designed to optimize the use of resources, reduce the impact of the city on the environment, and make life in the city more sustainable and convenient for its residents. As technology continues to advance, we can expect to see even more innovative and efficient solutions being developed to improve the quality of life in the cities of the future.

1.3 Mobility-as-a-Service

Mobility-as-a-Service, also known as MaaS, is a fast-growing transportation concept that offers a range of alternative transport solutions in a single platform. MaaS aims to provide customers with simplified access to various modes of transportation, including public transport, ride-sharing, bike-sharing, car-sharing, and other mobility services.

As the demand for more efficient transportation grows, MaaS has become increasingly popular among commuters, especially in urban areas. Below are the seven steps to MaaS:

1. **Integrating different modes of transportation.** To deliver an efficient MaaS solution, different modes of transportation, including public transit, car-sharing, bike-sharing, ride-hailing, and others, need to be integrated onto a single platform.
2. **Verification of users.** People who use MaaS must be verified to ensure accuracy and security. Users' identity verification is necessary when registering for MaaS services through an app.
3. **Reservation and booking.** MaaS integrates with third-party solutions that offer reservations and booking services across various modes of transportation.

4. **Routing and scheduling.** Real-time routing and scheduling are key components of MaaS solutions. Commuters need to be connected to their ultimate destination or next mode of transportation in the shortest, most efficient way for the mode of transportation they choose.
5. **Payment and billing.** MaaS solutions provide automated payments options for customers via subscription, or per-transaction-basis. By removing the need for separate transactions for each mode of transportation, it reduces the hassle and expense of multiple payments.
6. **Customer service and support.** To provide excellent customer service it's essential that queries and concerns are addressed on time. Customer support and feedback options, along with the provision of emergency safety features, are crucial aspects of MaaS.
7. **Data and analytics.** MaaS solutions use the wealth of transactional data generated by users, which helps maximize efficiency of the overall system by analyzing key metrics such as usage patterns, means of payments, and so on. This is essential in delivering an improved customer experience and minimizing costs.

Overall, Mobility-as-a-Service is revolutionizing how people commute across urban environments. By leveraging technology to integrate multiple transport modes, MaaS offers customers flexibility, convenience, and cost-effective travel.

1.4 Self-driving Cars

Self-driving cars are vehicles that operate autonomously without human input. They use a combination of sensors, cameras, and algorithms to interpret and respond to their environment. There are different levels of autonomy in self-driving cars, ranging from partial automation, where the driver is still responsible for some aspects of driving, to full automation, where the car can handle all aspects of driving without any human intervention.

The potential benefits of self-driving cars include improved safety, increased mobility for people who cannot drive, and reduced traffic congestion. However, there are also concerns about the ethical and legal implications of self-driving cars, as well as the potential loss of jobs for drivers.

Despite some pilot programs and developmental testing, self-driving cars are not widely available for public use yet. There are still many technical and regulatory challenges that need to be addressed before self-driving cars can become a reality for everyday drivers.

- Self-driving cars can potentially increase safety on the road, as they eliminate the human error factor.
- In a smart city, self-driving cars can communicate with each other and with the city infrastructure, optimizing traffic flow and reducing congestion.
- Self-driving cars can also reduce the need for parking, as they can drop off passengers and find a parking spot elsewhere, thus freeing up space in crowded urban areas.

– However, implementing self-driving cars in a smart city requires a significant amount of investment in infrastructure, sensors, and communication technology. It also raises questions about privacy, cybersecurity, and the possible displacement of human drivers.

1.5 Self-driving Projects over the World

There are a number of companies working on self-driving cars today [1,18–22] (see Fig. 2).

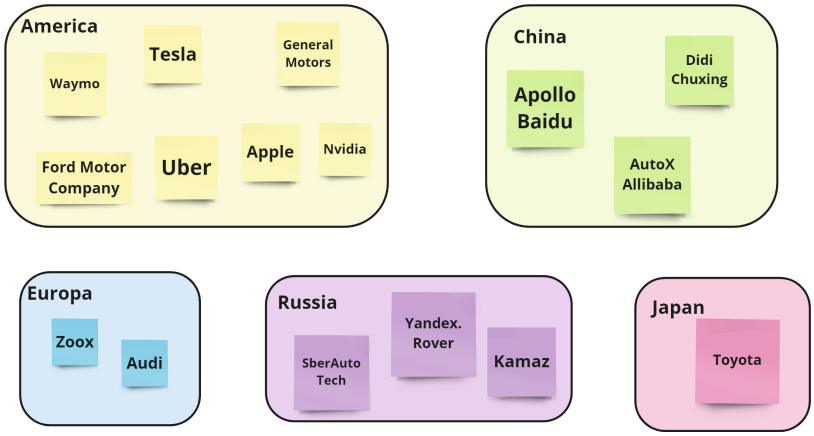

Fig. 2. Self-driving projects over the world

Self-driving car technology has been developing rapidly over the past decade, with major players such as Tesla [2], Google [3], and Uber [4] investing heavily in this field. However, these companies have different approaches and goals for their self-driving car projects.

Tesla's self-driving car technology is based on its Autopilot system, which includes radar, cameras, and ultrasonic sensors. It is designed to assist drivers rather than completely take over the driving experience. Tesla's goal is to develop fully autonomous cars, but the company has faced controversies over the safety of its Autopilot system after multiple accidents.

Google's self-driving car project, Waymo, uses a combination of radar, cameras, and lidar sensors to create a 3D map of the environment around the vehicle. Waymo aims to develop a fully autonomous car that can safely navigate any road condition. The company has been testing its cars in several cities and has already launched a ride-hailing service in Arizona.

Uber's self-driving car project uses a similar system to Waymo, but with an added focus on building a ride-hailing service. Uber's goal is to develop a fleet of autonomous cars that can replace human drivers. However, the program has faced setbacks after a fatal accident involving a self-driving Uber vehicle in 2018.

Other companies such as General Motors, Ford, and Nissan have also invested in self-driving car technology. General Motors' Cruise Automation has been testing its autonomous cars in San Francisco, and the company has plans to launch a commercial ride-hailing service in 2023. Ford is working on its self-driving car technology with Argo AI, and the company has plans to launch a fully autonomous vehicle in 2021. Nissan's ProPilot system [5] is designed to assist drivers on highways and in dense, urban environments.

While each company has its own goals and approaches, the development of self-driving car technology is expected to revolutionize the transportation industry. Fully autonomous vehicles could greatly reduce the number of accidents caused by human error and create new opportunities for ride-sharing services.

2 Challenges of Self-driving Cars in Smart City

As urban populations continue to grow, Smart Cities are emerging as a solution to tackle the rising environmental, social and economic challenges. Smart City infrastructure is built around the idea of using technology to create an efficient and sustainable environment for its citizens. One such technological advancement that has been making waves in recent years is self-driving cars. However, this innovation comes with its own set of challenges that need to be addressed before they can become a common sight in Smart Cities [6].

Several surveys have been conducted to identify the challenges that need to be overcome before self-driving cars can become mainstream in Smart Cities. These challenges range from technology issues to regulatory and ethical concerns. One of the biggest challenges is the need for technology upgrades in existing infrastructure. Smart Cities require high-speed communication networks and real-time data processing capabilities that can support the complex algorithms used by self-driving cars. Without these upgrades, self-driving cars will struggle to operate efficiently in such an environment.

Another key challenge is the issue of cybersecurity [7]. With the amount of sensitive data collected by self-driving cars, there is a real risk of cyber-attacks. It is crucial that cybersecurity measures are put in place to ensure the safety of the passengers and the system as a whole.

Regulatory and ethical concerns are also major obstacles that self-driving cars will face. There is a need for consistent regulations across different cities and countries to ensure the safety and reliability of the technology. Additionally, ethical concerns such as the decision-making process in case of an emergency need to be addressed to ensure that the technology is morally acceptable.

Next we will speak about technical map of communications between self-driving cars and smart city infrastructure.

3 Vehicle-to-Everything Communications

Vehicle-to-everything (V2X) communications is a wireless technology that allows vehicles to communicate with everything around them, including other vehicles, pedestrians, cyclists, and infrastructure such as traffic signals and road signs [17]. The picture 3 shows the main objects of V2X communications. It uses dedicated short-range communication (DSRC) technology to send and receive data between different types of devices.

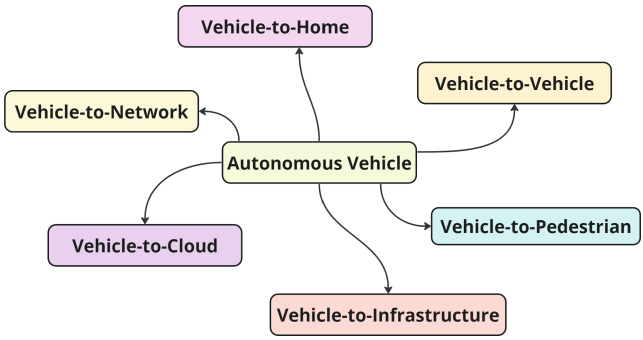

Fig. 3. V2X communications map

There are two types of V2X communications: Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). V2V communications enable vehicles to exchange information in real-time to improve safety and efficiency. This includes data on vehicle location, speed, acceleration, and deceleration. V2I communications allow vehicles to communicate with infrastructure such as traffic lights and road signs to provide drivers with real-time information, such as the optimal speed to approach an intersection or the presence of construction or accidents.

Overall, V2X communications can improve road safety and reduce traffic congestion by providing drivers with real-time information and warnings of potential hazards. It is also an essential technology for the development of autonomous vehicles.

Several existing frameworks have been established to assist in the implementation and deployment of V2X technology [23]. These frameworks provide a standardized approach for the development of V2X systems and enable interoperability between different systems. Here are some examples of existing frameworks in V2X technology:

1. Dedicated Short-Range Communications (DSRC): This is a wireless communication technology designed specifically for V2X applications. It operates in the 5.9 GHz frequency band and enables high-speed data exchange between vehicles and infrastructure.

2. Cellular V2X (C-V2X): This is a cellular-based V2X technology that uses existing cellular networks to transfer data. C-V2X has two modes of communication; direct communication (PC5) and network communication. Direct communication allows vehicles to communicate directly with each other, while network communication facilitates communication between vehicles and infrastructure.
3. European Telecommunications Standards Institute (ETSI) ITS: ETSI ITS provides a framework for the development of intelligent transport systems (ITS) in Europe. The framework covers V2V and V2I communication and includes standards for data exchange, network management, and security.
4. IEEE 802.11p: This standard defines a wireless communication protocol for V2X applications. It operates in the 5.9 GHz frequency band and enables high-speed data exchange between vehicles and infrastructure.
5. Society of Automotive Engineers (SAE) J2735: This standard defines a message set for V2X communication. It includes a set of messages for basic safety applications (BSM), such as collision avoidance and emergency vehicle alerts.

These frameworks provide a foundation for the development and implementation of V2X technology. As the technology continues to evolve, it is expected that these frameworks will evolve as well to accommodate new applications and technologies.

Vehicle-to-Everything (V2X) communication is an emerging technology that connects vehicles with infrastructure, pedestrians, and other vehicles through communication systems. V2X communication is poised to not only transform the automotive industry, but also to improve safety, efficiency and functionality in transportation. This review aims to evaluate the current state of the art in V2X communication.

Speaking about recent advances in V2X Communication, according to Elektrobit Automotive GmbH researchers, a new communication network called the Cellular V2X (C-V2X) has emerged recently, which has a high potential to change the existing communication paradigm. C-V2X is based on cellular networks and provides a reliable, low-latency, and high-bandwidth communication for V2X applications. C-V2X has been successfully tested in various countries, especially in China, where the technology has been adopted for use in smart cities.

In addition, in [8–10] conducted a study on cyber-physical vehicle networks. The authors developed a system to analyze and assess the communication link quality between vehicles during platoon movement, which resulted in significant improvements in communication efficiency. The authors proposed a unique encryption method for securing V2X communication, which can ensure the integrity of the message and prevent cyberattacks from malicious users.

Another research articles [11,12] proposed a new approach to vehicle-to-vehicle (V2V) communication using a road-to-vehicle (R2V) communication model. The authors showed that this approach has the potential to reduce the communication overhead of V2V communication, and improve V2V communication performance.

Furthermore, in works [13,14] developed a new communication protocol for V2X communication. The authors performed experimental studies to demonstrate the proposed protocol's increased efficiency in comparison to traditional IEEE802.11p standard, which currently serves as the basis for V2X communication.

Research by [15,16] showed that machine learning algorithms can be used in V2X communication to improve communication efficiency. The authors presented an adaptive modulation and coding scheme that employs machine learning algorithms, and demonstrated that the proposed method improves communication throughput by 25% compared to traditional methods.

In conclusion, V2X communication technology is continuously evolving. The review highlighted the recent advances in V2X communication, such as the use of cellular networks, cyber-physical vehicle networks, R2V communication model, new communication protocols, and machine learning algorithms. These innovations in V2X communication have led to improved communication efficiency, increased reliability, and enhanced cybersecurity, which will ultimately lead to safer and more efficient transportation systems.

4 Data Aspects

Data collection in self-driving cars is essential for their functioning. Self-driving cars collect data from various sensors, such as lidar, cameras, radar, and GPS. The data collected is used to create a real-time 3D map of the car's surroundings. The amount of data collected by self-driving cars is massive, with some cars collecting up to 4 terabytes of data per day. The data collected is used to improve the accuracy and reliability of the car's decision-making process. Data collected from self-driving cars is analyzed using machine learning algorithms to improve their performance. The collected data can help self-driving cars learn from past experiences and avoid mistakes in the future. The data collected is highly sensitive and must be secured to prevent unauthorized access. The collected data can be shared with regulators and researchers to improve the overall safety of self-driving cars. Large tech companies and traditional automakers are investing heavily in collecting and analyzing data from self-driving cars. The accuracy and reliability of self-driving cars are directly proportional to the amount and quality of data collected. Self-driving car companies use simulation to collect additional data to improve their algorithms' performance. Self-driving car companies collaborate with each other to share data and improve each other's technology. The collected data can be used to create detailed maps of roads, including lane markings, traffic signs, and road conditions. Self-driving cars must collect a wide variety of data, including weather conditions and pedestrian traffic. The data collected from self-driving cars is invaluable for improving traffic flow and reducing congestion. Self-driving car companies must comply with laws and regulations governing data privacy and security. The collected data must be stored securely and accessible only to authorized personnel. The data collected can be used to improve other autonomous technologies outside of the automotive industry.

The data collected can also be used to improve urban planning, public transportation, and infrastructure management. The life circle of data shown on Fig. 4.

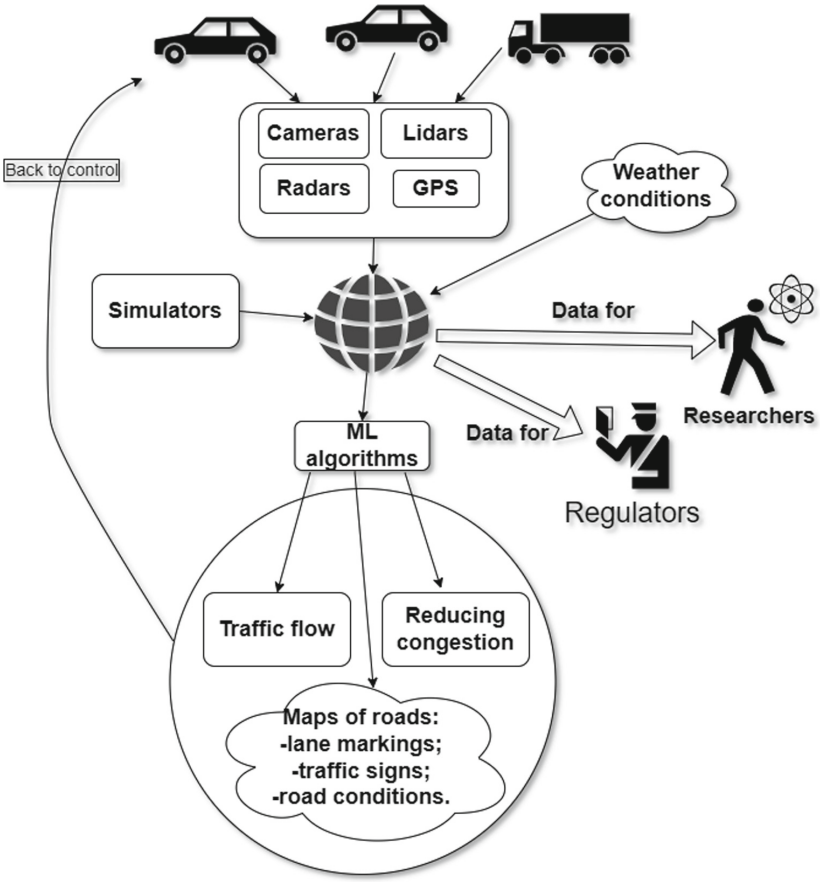

Fig. 4. Data life circle

Autodata is a popular software program used in the automotive industry. It provides information on a wide range of vehicle makes and models, including repair and maintenance procedures, service schedules, wiring diagrams, and technical specifications. Autodata is widely used by mechanics, automotive technicians, and other professionals who work with cars and trucks. It is designed to simplify the access and use of technical data by offering a variety of user-friendly features. Autodata includes thousands of pages of repair and diagnosis information that is continually updated to keep pace with changes in the automotive industry.

5 Future Research - Autonomous Trucks and Delivery

The topic of Unmanned logistic corridors is very interesting to future research.

Unmanned logistic corridors, also known as autonomous logistics corridors, are systems that use intelligent, autonomous vehicles to transport goods and materials without human intervention. These corridors are designed to improve transportation efficiency, reduce costs, and increase safety by removing the need for human drivers.

The concept of unmanned logistic corridors is in its early stages of development and has been primarily discussed in relation to the transportation of goods between warehouses and distribution centers. Some companies, such as Amazon and DHL, have begun testing autonomous delivery drones and trucks for last-mile delivery, but corridor-scale implementation is not yet widespread.

Several governments and industry organizations are exploring the potential of unmanned logistic corridors, including the United States Department of Defense and the European Union. These initiatives aim to develop cutting-edge technologies for transportation and logistics, including advanced sensors, GPS, and AI algorithms.

The potential benefits of unmanned logistic corridors include increased efficiency, reduced transportation costs, and improved safety. However, the implementation of these systems also raises concerns about job displacement and cybersecurity risks.

6 Conclusion

In conclusion, the survey of self-driving car challenges in Smart City infrastructures highlights the need for a comprehensive strategy to overcome the challenges associated with this technology. Technology upgrades, stronger cybersecurity measures, ethical and regulatory frameworks and public education will all play a crucial role in ensuring the success of self-driving cars in Smart Cities.

Acknowledgements. The author would like to thank Vladimir Korkhov for useful advices for the opportunity to work on this theme.

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