

Recent Advances in Autonomous Vehicles for Peer-to-Peer Communication

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Abstract—For a safe and effective commuting experience in the near future, autonomous vehicles are a growing technology. 85% or more of traffic accidents could potentially be avoided with the use of autonomous vehicles. Drivers could also skip boring tasks and enjoy their rides. Because of these benefits, "57% of customers worldwide trust autonomous cars - much more so in emerging nations," according to Cisco's survey. Self-driving cars, or autonomous vehicles, are able to communicate with everything around them. This communication environment lacks security and contains a number of weaknesses. Trustworthiness, correctness, and security of received and broadcasted data in the communication channel are the main problems in autonomous vehicle (AV) communication. Automobile communication systems, which electronically relay road conditions, are crucial components of autonomous vehicles. Conventional wireless technologies immediately show their incapability when data traffic expands dramatically due to their limited capacity. Researchers have attempted to make driving simpler and more convenient, but they risk complicated accident investigations. Car manufacturers have made great efforts to meet consumer needs. This paper examines recent technological developments enabling peer-to-peer communication in autonomous cars.

Index Terms— Autonomous vehicles, Communication system, Peer-to-peer communication, and Traffic accidents.

I. INTRODUCTION

The automobile business is changing as a result of autonomous vehicles. The next-generation transportation infrastructure in every nation will be based on autonomous cars, which enable movement for people, increase productivity, and enhance quality of life. Automation in vehicle networks and technological improvements in metropolitan areas where the old transportation system is becoming increasingly disorganised and inefficient will increase road safety and ease congestion. An autonomous car is one that has an autopilot system and can move from one location to another without the assistance of a driver. According to another definition, an autonomous vehicle is one that can navigate and sense its environment without human intervention. To enable completely autonomous driving, radar, ultrasonic, and optical cameras synchronise and communicate with one another. [1] The development of driverless cars will have a huge impact on businesses and professions. For employee transportation or delivery, automated cars could, for instance, replace business fleets. Also, employees could increase the number of productive hours in their day by working instead of driving during their regular travels. Innovations in this field have the potential to completely change the vehicle insurance business by reducing accidents. Accidents will significantly decline by 80% by 2040, according to a new study [2].

How autonomous vehicles operate:

The software of the vehicle chooses a path when the driver chooses a location and starts the engine. A rotating Light Detection and Ranging (LIDAR) sensor positioned on the vehicle's roof scans a 60-meter circle around it to produce a live, three-dimensional image of its surroundings. A sensor on the left rear tyre monitors sideways motion in order to calculate the car's location in reference to the 3-D map. Radar devices in the front and rear bumpers gauge obstruction distances. 3, All of the sensors are linked into the car's artificial intelligence programme, which also collects data from Google Street View and cameras. The AI simulates human perception and decision-making processes to control driving systems, such as steering and brakes. The car's software accesses Google Maps in order to be aware of things like landmarks, traffic signs, and lights beforehand. A person can take control of the vehicle using the override capability. Individual automobiles may find use for information from surrounding vehicles, notably information concerning traffic congestion and safety hazards. In vehicular communication systems, vehicles and roadside equipment act as the communication nodes of a peer-to-peer network that exchanges information. Technology utilised in AV includes Autonomous vehicles may sense their surroundings using a variety of technologies, including radar, laser light, GPS, odometers, and computer vision. The optimum routes to take, as well as obstructions and appropriate signage, are determined by modern control systems' analyses of sensory data. Autonomous vehicles include control systems that can analyse sensory input to discriminate between various vehicles on the road in order to create a route to the desired site [4].

Modern vehicles are more sophisticated, swifter, and efficient. These advancements are made possible by a large number of electronic control units (ECUs) and the extensive communication network that links them. Thanks to these developments, drivers can now enjoy a completely new driving experience with vehicles that can be remotely locked or unlocked, started without an ignition key, and driven or parked on their own. Competition amongst automakers has recently increased to include innovative driver-focused features in addition to physical car design, engine power, and performance. Soon, there will be a greater number of autonomous vehicles on the road, which is expected to improve road safety. It's not just new cars that are equipped with this new technology; even older cars share some of these characteristics and architectural elements. The vehicle's ECUs contain hundreds of megabytes of code that enable these distinctive driving features, but security challenges still exist [5]. Today, in the 21st century, there are computers on wheels everywhere around us rather than mechanical cars. A wide range of auto safety features and protocols, such as forward-collision warning, automatic emergency braking, vehicle-to-vehicle communications, and eventually fully autonomous vehicles, can already be developed using these technologies. Ad hoc networks utilised by the Intelligent Transportation System (ITS), such as cellular networks, Wireless Access Vehicular Environment (WAVE), and Dedicated Short-Range Communication (DSRC), do not offer secure data transfer [6]. At the moment, vehicle communication security measures are built on outmoded cellular and IT standards, rendering them inappropriate for ITS applications. However, several academics are working to create a standard ITS security strategy [7]. Transportation could be dramatically changed by autonomous transportation choices. Their qualities and potential uses will also have an impact on land use and urban development. These include the amount of parking available, the layout, and how desirable a location is as a place to live, shop, or work. Also, the deployment of driverless vehicles may allow for new uses for land currently used for parking and transportation (either for other transport uses, such as walking or cycling, but also for construction purposes) [8]. The widespread use of the Internet of Things (IoT) in numerous industries, applications, and services is proving to be disruptive. Feeling the physical world, analysing the data, drawing sensible judgements, and acting have never been conceivable. The distinction between the physical and digital worlds is blurring, making innovation feasible. This has been particularly evident during the last few years in the realm of transportation systems. A few of the onboard decision-making units and remarkable array of sensors that connected vehicles have [9, 10] to expand their support to drivers include cruise control, parking, collision warning, lane-changing warning, pedestrian detection, platooning, and cooperative coordination in which the driver may no longer be required in the next decades thanks to the deployment of cutting-edge sensors. The focus of this work is the hyperconnected vehicle, which is best represented by an autonomous electric vehicle (EV), such as a car, that can communicate between itself and its environment and actively engages in complicated cross-domain activities, such those occurring in smart cities. It would be wise to disseminate this knowledge via V2V communication as soon as is practical in order to execute cooperative movement planning and cooperative driving [11]. In this case, the first passing vehicle assesses the situation and informs the following vehicles, etc. Eventually, this local status is communicated to all passing cars, enabling them to act even before their own sensors are made aware of the threat. Unfortunately, this situation is dependent on the density of the vehicles and is susceptible to outside threats like incorrect information (other vehicles).

The term "connected car" is also being used more frequently to describe cars that are always online and capable of communicating with infrastructure and other vehicles via vehicle-to-vehicle (V2V) services. Ten years have passed since remote diagnostics and vehicle health reporting became widely used. In addition to V2I and V2V, vehicles are becoming more and more "hyperconnected," or "vehicle-to-everything (V2X)," where they communicate and exchange information with any object that has the capability to do so, including pedestrians, devices, power grids, and other entities. Also, we have witnessed the development of autonomous self-driving vehicles using artificial intelligence, in which the driver may no longer be required in the next decades thanks to the deployment of cutting-edge sensors. The focus of this work is the hyperconnected vehicle, which is best represented by an autonomous electric vehicle (EV), such as a car, that can communicate between itself and its environment and actively engages in complicated cross-domain activities, such those occurring in smart cities. It would be wise to disseminate this knowledge via V2V communication as soon as is practical in order to execute cooperative movement planning and cooperative driving [11]. In this case, the first passing vehicle assesses the situation and informs the following vehicles, etc. Eventually, this local status is communicated to all passing cars, enabling them to act even before their own sensors are made aware of the threat. Unfortunately, this situation is dependent on the density of the vehicles and is susceptible to outside threats like incorrect information (other vehicles).

II. CLASSIFICATION OF AUTONOMOUS VEHICLES

This technical study specifies standard language for concepts linked to cars with automated systems. Mutually exclusive stages of driving automation. (SAE J3016 Standard, 2016) This requirement complies with levels established by the German Federal Highway Similar to the National Highway Traffic Safety Administration, Research Institute (BAST) (NHTSA). In 2014, the National Highway Traffic and Safety Administration has classified autonomous vehicles based on level of automation and technology used in the vehicle.

The six divisions are listed below:

- Currently, the great majority of cars and trucks are at Level 0 (No automation). The driver controls the steering, throttle, and braking (ST&B), keeps an eye on the surroundings, navigates, and decides when to turn, change lanes, and brake. However, some warning systems may exist (blind-spot and collision warnings).
- Driver assistance level one: This level of vehicle can do S or T&B, but not always, thus the driver must be prepared to take over those duties when necessary. That requires the driver to remain attentive to what the vehicle is doing and to be prepared to intervene if necessary.
- The great majority of automobiles and trucks are at Level 0 (No automation) at this time. Level 2 (Partial help): When the driver notices object or events the automobile isn't responding to, the car quickly relinquishes control to the driver and manages ST&B. The driver is in charge of keeping an eye on the environment, traffic, weather, and road conditions in the first three tiers.
- Level 3 (Conditional assistance): In specific environments, like motorways, the automobile monitors the surroundings and handles all ST&B. However, the driver must be prepared to step in if the vehicle does.
- Level 4 (High automation): The automobile manages ST&B and keeps an eye on its surroundings in a larger variety of circumstances, although not all of them, such inclement weather. When it is safe to do so, the driver engages automatic driving. The driver is not necessary after that.
- Level 5 (Full automation): The only actions required from the driver are to start the vehicle and establish the destination. Any lawful destination can be reached by the vehicle, and it is free to make decisions along the way. (SAE J3016 Standard, 2016).

III. RECENT ADVANCES IN ESTABLISHING PEER TO PEER COMMUNICATION

A. Establishing peer-to-peer vehicular communication environment using blockchain technology

Blockchain technology offers a fully distributed and open database or ledger for any kind of data exchange. There is a comprehensive description of every transaction ever made. The fundamental component of a blockchain is a block, which contains a record of some of the transactions that took place during a certain amount of time. A block can be imagined as a single bank statement. Blocks are linked chronologically using hashes [14] to ensure that no one can tamper with this ledger while keeping it available to everyone. Each new block contains the hash of the previous block. Because of this, altering it requires first changing all of the block hashes. A blockchain also gets stronger as it accumulates data. A fundamental concept in blockchain technology

is consensus. A blockchain is more powerful than traditional databases because of its decentralised nature. Nonetheless, it can also be applied by shady and mysterious parties. Since anyone can post data to the blockchain [15], the contributed data must receive approval from all other operators.

A blockchain is technically made up of an almost limitless number of blocks that are cryptographically connected in a particular order. Each block of the blockchain is made up of transactions, which operate as a substitute for the actual data to be added to the chain. Every blockchain is connected to every other blockchain for the exchange of IV runtime data. If a vehicle travels through one blockchain zone and then another, the data on the vehicle can be extracted and transferred to the current blockchain (the blockchain region next to the vehicle) (from where the vehicle recently passed). During this cycle-like process, all blockchains exchange information on all IVs [16, 17]. The summary (event-based data) of IVs is recorded on the local dynamic blockchain (LDB). For example, if a car commits an unusual activity, the blockchain will store that action along with the car's unique information in the second layer of the main blockchain (MB), and if nothing unexpected happens, the blockchain will gradually replace the database (about 6 months) [18].

B. Integrating shared autonomous vehicles into a Peer-to-Peer Communication:

Higher matching rates are produced by peer-to-peer (P2P) ridesharing systems because they draw more drivers than pure ridesharing systems. Even easing the participants' spatiotemporal constraints may increase the likelihood that they will match. However, it has been found that P2P ridesharing systems by themselves do not guarantee matching when the number of drivers is limited. We recommend employing a fleet service in P2P ridesharing to cover the unmatched riders. This system explores the usage of shared autonomous vehicles as a fleet even though any fleet service, such as taxis, Uber/Lyft, or paratransit, may be employed because they can be sent automatically. This simulates an integrated system for peer-to-peer ridesharing and shared autonomous fleet vehicles (SAFVs).

In this integrated shared mobility system, there are three main types of system participants: shared vehicle drivers (SD), shared vehicle riders (SR), and shared autonomous fleet vehicles (SAFVs), which the SRs use as a shareable form of transportation. The ridesharing matching difficulty is addressed by [19] providing a "time-expanded viable (reduced) network" to lessen the complexity of matching for each distinct rider and driver. They discretize the time horizon in 5-minute time steps, even though the method also functions for shorter time periods. Using this concept, each SR in our study has a set of connections that SDs can use to go there. Each connection is combined with the time proximity, which includes the arrival time of the link start-node and the departure time of the link end-node. Further study along these lines will need to be done for more effectiveness [20].

C. Peer to Peer Communication Between the Autonomous Vehicles Using Virtual Private Network:

To prevent accidents, both industrialised and emerging nations are particularly interested in creating transportation systems based on autonomous vehicles. Autonomous vehicles are made of a combination of hardware and software. Hardware and software must work well together to build a great autonomous vehicle.

To provide the greatest service possible in the field of autonomous vehicles, it is imperative that the processing, analysis, and sharing of geospatial data with autonomous vehicles for improved mobility be addressed. The geospatial information will help the autonomous vehicles locate the quickest path, identify objects, and pass along the geospatial information to the next autonomous vehicle when it is ready. By doing so, effective peer-to-peer communication will be strengthened [21]. The study that Guruprasad et al. [2021] proposed One virtual private network connects each autonomous vehicle travelling in a certain cluster. Each city will be treated as a separate cluster in this case. Before any new autonomous vehicles may join this cluster, the administrator must allow them. This can happen automatically, similar to when a user joins a new Wi-Fi network. After acceptance, the vehicle will be followed until it leaves that particular cluster [22]. A clustering technique has been developed to assist users in creating clusters and locating autonomous cars that are travelling within such clusters.

The autonomous vehicle's every move will be watched from the server side over a VPN connection. Every vehicle has the ability to communicate with the VPN server. Consider the case of a car moving between a source and a destination. The autonomous car will communicate such information with the VPN server and publish it to all of the other vehicles in that cluster if there is significant traffic there or if a natural disaster has happened. With this information, the autonomous vehicles can select a different path to their destination. Using this strategy, the system will be built to allow communication amongst autonomous vehicles to increase mobility. The automobiles will speak with one another over VPN. The VPN is crucial when sending information to numerous automobiles.

D. Multi agent systems in a peer-to-peer network using the decentralized Ethereum Blockchain technology:

When combined into a multi-agent system, autonomous agents play a vital role in data exchange and work in the current automation of business operations. There are currently trading bots, data collectors, and other business applications of software agents. If this pattern holds, eventually every industry and corporation will adopt robotic multi-agent systems and incorporate them into their daily operations, whether they are mobile robots or intelligent items. Furthermore, without a communication infrastructure that permits secure, unified communication among the participants, autonomous agents cannot work on complex business processes [23].

One of the key innovations that emerged with the development of Blockchain is the technology of smart contracts, which is executed by a computer device in a decentralised network. As was demonstrated for the first time in the development of the Ethereum protocol [24], this method may be applied to convey commands between agents in the form of data or executable code in real-time. The protocol allows the development of any custom logic, storage of the resulting algorithm and data on a public Blockchain, and execution of the algorithm. Because of the public Blockchain's capacity to support programming, which enables agents to interact with one another and execute commands [25].

One example of a multi-agent system that used the blockchain protocol for business is the autonomous intelligent robot agent (AIRA). The main objective of AIRA is to formalise communication and information exchange between robotic networks and smart contracts. The protocol allows a large variety of different agents to be connected to a larger network where each agent can request and provide different services, such as the transfer of data from agent sensors, moving to a specific location, transporting cargo, and any other task that autonomous agents are capable of performing. The service can be requested by a user who has the protocol installed on their machine or by an agent from another agent. This protocol is suitable for agents involved in any activity where a secure protocol is necessary, whether it is commercial, controlled by agents who generate income, or nonprofit. The Robot Operating System's high-level industrial communication architecture is supported by this proposed study, which connects all suitable agents to the Ethereum network's smart contracts (ROS). The system stores data in the Interplanetary File System (IPFS) distributed file system, and agents can access its contents using encrypted identities. To execute transactions between agents (ether), AIRA uses both Ethereum network tokens and its own network tokens (air-tokens) [26].

E. Millimetre-Wave Wireless Communications between two vehicles for IoT-Cloud in Autonomous Vehicles

Autonomous vehicles must have communication systems that electronically transfer information about the road. Due to their limited capacity, traditional wireless technologies initially become ineffective when data traffic suddenly increases [27]. The next-generation wireless technology, mm Wave, and its inter transmissibility and beamforming approach are proposed by Linghe Kong in e.at.el.2017 [28]. Based on these characteristics, this paper proposes a novel design for a vehicle millimetre Wave system that combines the benefits of cloud computing with the Internet of Things. This mm Wave technology provides multi-gigabit data sharing about the local surroundings as well as cloud-based real-time object detection by autos. As a result, autonomous vehicles can make the best driving decision right away. When a car turns in a specific way in regard to other cars and the roadside infrastructure. The three key actors in the framework that was created are:

1. All self-driving cars are equipped with the usual sensors, such as a camera, a LiDAR, and a mmWave radio.
2. The roadside infrastructure consists of a mmWave radio and an HD camera. Moreover, a cable connects the cloud with the infrastructure.
3. Data analysis and journey planning are both made possible by cloud computing.

This framework offers services based on the depicted V2V and V2I communication modalities.

mmWave V2V communication When automobiles can communicate using mmWave radios and share real-time sensory data, an IoT application is produced. The problems with the blind region and the severe weather are therefore successfully overcome. For further information, see How Blind Areas Are Detected. When a vehicle discovers a blind area within its sensing range, it asks surrounding cars for camera or light detection and ranging (LiDAR) data to make up for it. Furthermore, while the mmWave's transmission range is essentially unaffected by bad weather, the LiDAR's detection range is greatly reduced. Using shared sensory data and multi-source multi-modal data processing, a vehicle may reproduce the 3D road conditions [29].

Data is sent between autos and the cloud using the roadside infrastructure as a relay in V2I type of communication.

Hence, the recognition problems can be successfully fixed. For instance, when a vehicle detects an object or a human gesture but is unable to identify it, it may upload HD imagery to the cloud. The cloud can immediately

finish the recognition and report the findings back since it has the capacity to analyse massive amounts of data and run complex computations [30].

IV. CURRENT ADVANTAGES AND LIMITATIONS OF AUTONOMOUS VEHICLES

At the start of each new paragraph, mention the section's summary.

Possible Benefits: More autonomous vehicle deployment could lead to fewer accidents and traffic collisions (resulting deaths and injuries and costs).

- Greater traffic flow management and a reduced demand for safety gaps result in increased road capacity and fewer traffic bottlenecks.
- A stiffer max speed limit for self-driving cars.
- A reduction in the amount of area needed to park cars.
- A decrease in the cost of motor insurance and a lack of necessity for traffic enforcement.
- A decrease in auto theft due to the car's greater visibility.
- Removing the steering wheel increases fuel efficiency.
- Relieving drivers and navigators of their driving and navigational duties, allowing them to finish [32, 33].

Limits include the duty to prevent injury and the loss of driving-related jobs (for all driving professions, including lorry drivers, bus drivers, taxi drivers, etc.).

- Encroachment on private space.
- Explosive-filled self-driving cars might be used as a weapon.
- The navigation system's potential impact from the weather.
- Areas under temporary construction that aren't marked on maps or databases.
- Determining whether it is safe to cross a pothole or piece of debris by determining the severity of traffic lane obstructions.
- Today's law enforcement personnel and other pedestrians make gestures and nonverbal cues that are improper for driverless cars.
- Cybersecurity (because data is sent through V2V (vehicle to vehicle) and V2I (vehicle to infrastructure) protocols, there is also a chance that an automobile could be hacked).
- The development of governmental guidelines and the implementation of a framework for autonomous vehicle legislation.
- Using autonomous vehicles instead of human drivers results in less experienced drivers.
- The refusal of drivers to give up control of their vehicles.
- Reduce reliance on public transportation
- Cybersecurity (because data is sent through V2V (vehicle to vehicle) and V2I (vehicle to infrastructure) protocols, there is also a chance that an automobile could be hacked) [34].

V. CONCLUSION & FUTURE ENHANCEMENTS

The lives of humans will be significantly made simpler by the autonomous vehicles of the next generation. Besides with relieving the driver's workload, they give passengers freedom while they travel long distances. The majority of research, however, is being done in the area of designing transportation systems based on autonomous vehicles. Researchers are working in tandem to develop the best hardware and software solutions for developing the best autonomous vehicles, and in the future, all autonomous vehicles will have a fixed camera that rotates 360 degrees when a signal is received from a particular vehicle. This camera will be used to observe real-world situations and interpret them. Industrial operations must also be carried out by workers from a variety of backgrounds, such as loading and delivering cargo utilising an unmanned aerial vehicle and a manipulator. In order to improve the functionality and use of autonomous vehicles, security, trust, and privacy issues in the relatively young field of autonomous driving must be addressed.

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