Survey on Vehicular Cloud Computing and Big Data

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***Abstract*—Modern transportation has become more efficient with the addition of sensors in vehicles. This has not only benefitted the in-vehicle experience but also has helped in generating and processing big data. A vehicular ad hoc network (VANET), was introduced to handle the network creates between vehicles. But this technology has not been able to keep up with the complex data that modern vehicle sensors are generating as it requires processing and managing capabilities, which are currently lacking in this network. Vehicular cloud computing (VCC) is a new way of deploying compute-intensive applications on vehicles. This is the product of combining VANET and cloud computing. This has many benefits, such as lower transportation costs, reduced congestion, and improved safety. But it also has some drawbacks. The paper discusses some of the challenges in the vehicular cloud network and the management of big data in it. We discuss the architecture and types of VCC, as well as its characteristic of VCC. Subsequently, we discuss the applications and advantages of VCC when used with big data. At last, the security challenges of VCC are discussed in conjunction with big data.**

Keywords— Vehicular ad hoc network, vehicular cloud computing, big data, issues, applications, architecture.

I. INTRODUCTION

Each day, modern automobiles produce about 25 terabytes of data. While experts predict that data generated by autonomous vehicles would reach 3,600 terabytes per hour[2]. Big data refers to enormous, complex data sets that are difficult to store, analyze, and visualize for future actions or results [3]. This data when stored and analyzed in the cloud can generate important insights. Transit service quality can be assessed by better understanding travel behavior using big data [4]. A lot of research has been put into how to increase the security and privacy of big data using cloud computing [5].

Vehicular Cloud Computing is a term that refers to the use of cloud computing platforms to provide computing capabilities in the vehicles themselves by collecting big data through offline and online application services [6]. This concept has the potential to make a huge impact on the automotive industry by allowing vehicles to have greater autonomy and increased computational power. It could also lead to new kinds of automated driving systems that are more efficient and safer than current models. By tapping into the cloud, vehicles can access a wide range of services, including apps, web browsing, navigation, entertainment, and much more. These services can further be improved by studying the big data generated by them.

Vehicular Cloud Computing (VCC) combines the benefits of cloud computing with the advantages of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication systems [6]. VCC systems use sensors, such as radar or LIDAR, to detect surrounding vehicles and pedestrians. They can also gather information about the movement and location of cars in real-time. Short-range communication (DSRC) protocol and 4G cellular connection are used for the exchange of large amounts of data [7].

Depending on the type of application being accessed, vehicular cloud computing could lead to several potential benefits. First and foremost, it could improve safety by reducing driver workloads and improving overall vehicle performance. Second, it could reduce costs by reducing the need for additional onboard hardware or software infrastructure. And finally, it could improve user experience by enabling autonomous vehicles to offer more intuitive features and performance levels than current models. VCC can help reduce the cost and complexity of both sharing infrastructure and providing autonomous driving services. It can help ease congestion and enhance traffic flow. Depending on the application, there may be many other advantages. Below is a flow chart depicting the topics that will be discussed further in the paper.

II. RELATED WORK

An Internet of Connected Vehicles (IoV) network model-based service-oriented network optimization model was described in the study [21]. Three key networking entities are

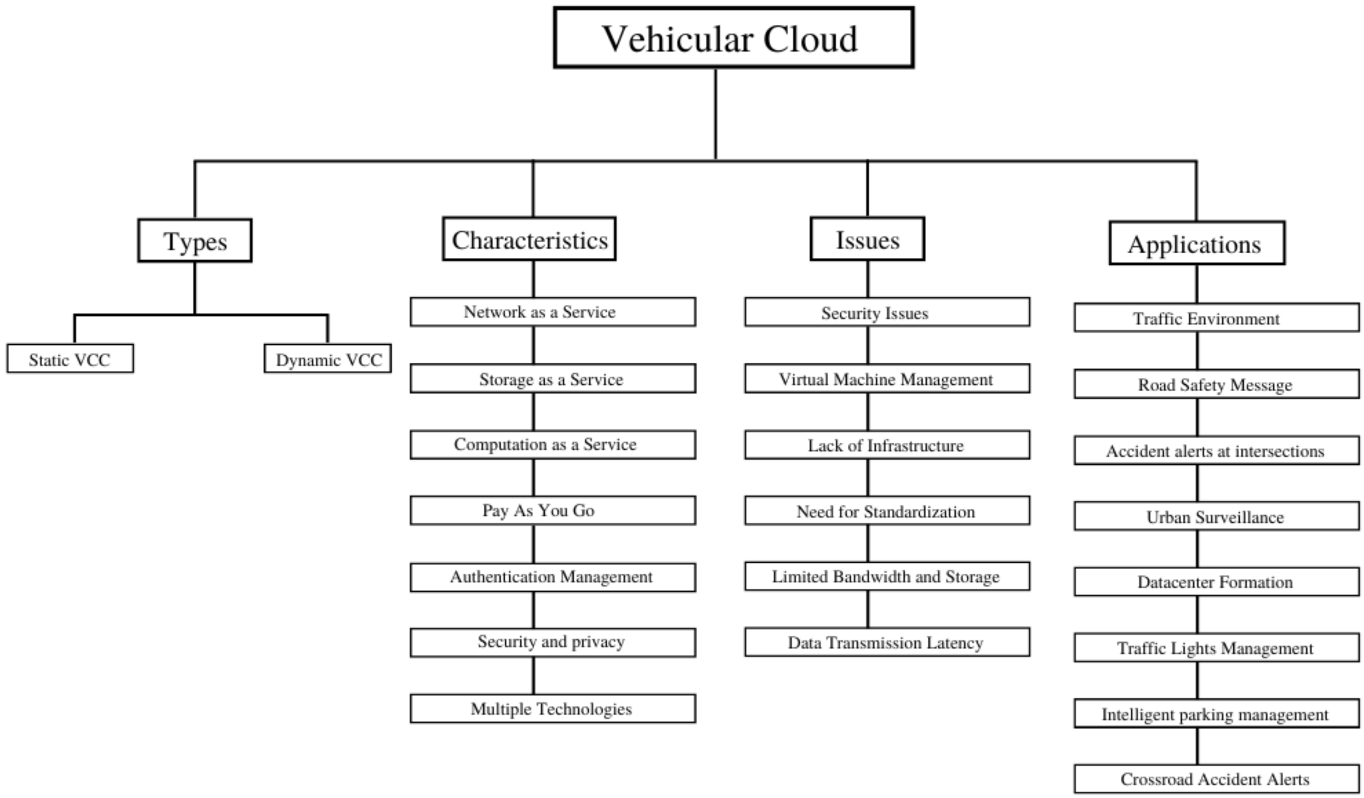

Fig: Topics covered in the paper

vehicular cloud, heterogeneous communication, and smart utilization cases in this network model. The majority of traffic-related data-oriented computations were performed at cloud servers to make intelligent decisions. Heterogeneous vehicular environments may utilize handoff-centric network communication with the connection component. The network model may be utilized to deliver service-oriented smart traffic services. The model was tested to affirm several service advantages in vehicular communication environments to test several service-oriented metrics. A mathematical model was also introduced to support the heterogeneous vehicular network implementation by implementing content-centric services and prioritizing network services.

The paper [8] is mainly concerned with the study of intelligent transportation systems (ITS) using big data analysis. However, the use of big data in VCC is missing. The authors introduced the survey by describing the history and characteristics of big data analysis as well as ITS. The architecture of big data analysis in ITS is also discussed, consisting of three layers: the data collection layer, data analytic layer, and application layer. The authors looked at large data applications in the ITS context, such as managing rail transit, predicting traffic flow, and preventing accidents. Numerous uses for big data have been found, including managing rail transit, predicting traffic flow, and preventing accidents.

To better comprehend VCC and its uses in conventional VANETs and VCCs, the paper [9] presents an overview of VCC and its security. Big data produced by VCC applications as well as VCC designs, applications, security issues, and dangers are discussed.

The author of the article [41] first discusses the technology used by VANETs to effectively and reliably transfer large amounts of data. The techniques using big data to analyze the features of VANETs and enhance their performance are then explored. Additionally, the author presents a case study in which machine learning techniques are used to analyze measurement data from VANETs to effectively detect unfavorable communication situations. Additionally, a case study demonstrating the utilization of urban VANET measurement data to identify NLoS (Non-Line-Of-Sight) conditions using machine learning techniques is presented.

Two new paradigms, vehicular cloud computing, and information-centric networking were proposed in [10]. A vehicle cloud is created when vehicles collaborate to provide

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value-added services using their resources. VCC, Vehicles can find and share resources thanks to a paradigm for vehicular computing. This enables them to work together to create value-added services. Information-centric networking is used to distribute vehicle clouds efficiently. The vehicular cloud network is developed based on them in the future. Design principles are discussed from three perspectives: system, networking, and service.

A thorough investigation into VCCs was done by [11]. By linking a conventional VANET, a VCC seeks to advance VANETs toward autonomous driving. The researchers first described the concepts of cloud computing, VANETs, VCCs, and mobile cloud computing to introduce VCCs. Their approach includes the following services: NaaS, SaaS, CaaS, StaaS, and Coaas. New VCC applications like traffic management, disaster management, and autonomous vehicle control are described. Despite its importance in terms of security and privacy issues, big data is not considered in this approach.

The authors of the paper [12] explore several technology platforms and software architectures for transportation, along with a broad range of storage, processing, and analytical techniques, and discusses issues with Big Data analysis. This paper provides a range of suggestions for how cities may utilize Big Data in transportation to build safe and sustainable traffic systems. Because Big Data and transportation research is, for the most part, in the beginning, the problems identified in this article are not addressed.

The frameworks for using vehicle onboard resources to deliver cloud services and outlines the design problems and research issues were discussed in [13]. Then the author examines mobility generators, vehicular ad hoc network simulators, and vehicular data sets as part of a detailed study of vehicular cloud computing. In this way, the paper offers a thorough overview of vehicular cloud computing and suggests potential directions for future research.

The concept of Fog Computing is discussed in [14]. Fog Vehicular Computing (FVC) is a novel approach to computerization. FVC uses the fog model, in which data processing and analytics take place close to the endpoint devices where vast amounts of data are generated, to increase the computation and storage capabilities of fog computing. However, the performance of FC can be degraded by the number of demands by patrons. An FVC architecture is proposed to counter this. There are some open issues and future directions for future research in the FVC context are also discussed.

III. Types of VCC

Vehicular cloud computing can be classified into two types:

- Static VCC: Companies are looking to take advantage of parking's idle computing resources by turning vehicles into data storage centers. Parking has traditionally been a time-consuming activity. People have parked their vehicles in shopping malls, airports, workplaces, and hospitals. Static VC (Vehicular Cloud) combines computer clusters with storage resources and computational power to create data storage centers.
- Dynamic VCC: Vehicles on the cloud can form dynamic virtual communities because of their high mobility and the rapid changes among networks. The cloud head, one of the vehicles, invites all nearby vehicles to join for the formation of dynamic VCs. Exchange and process of data occur while the vehicle is moving.

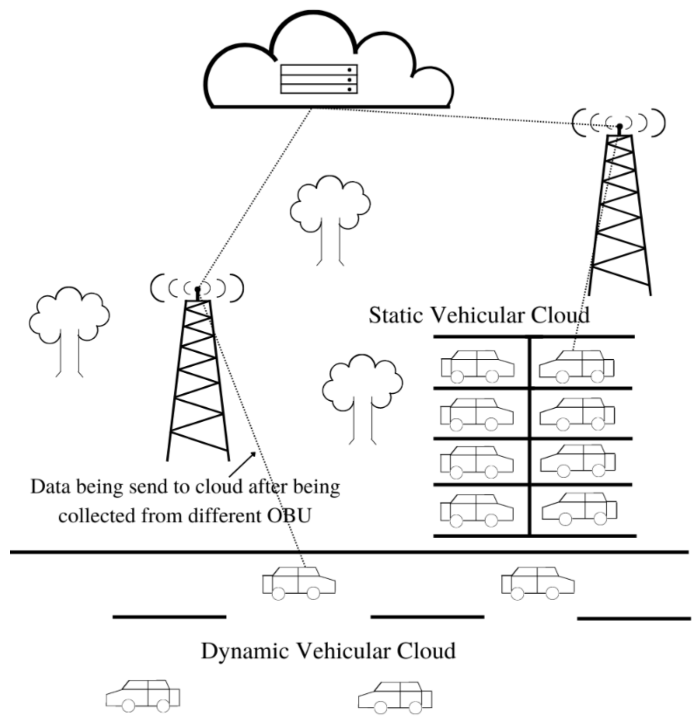

Fig: Different type of VCC

IV. Vehicular Cloud Architecture

A vehicle cloud computing architecture is similar to a traditional server-centric architecture designed for cloud storage and computational processing. The main difference is that the vehicle cloud computing architecture is designed specifically for the needs of vehicles in terms of security, data integrity, and performance. It might also include additional features such as remote diagnostics and centralized fleet management. The vehicle cloud computing architecture can range from a simple server-based solution to complex high-performance systems that can handle dozens of users at once. Although there are many benefits to this particular type of

Article	Year of Publication	Cloud Computing	IOV	VANET	VCC	Big Data	Big Data in Vehicular Network	Architecture	Security	Privacy	Remarks
[21]	2022	Y	Y	Y	N	Y	N	N	Y	Y	A heterogeneous network model has been suggested for IOV network
[8]	2019	Y	N	Y	N	Y	N	Y	N	N	Big Data analytics in ITS has been discussed
[11]	2019	Y	N	N	Y	N	N	Y	Y	Y	Detailed comparison between VCC and VANET applications
[12]	2019	Y	N	N	N	Y	N	N	Y	Y	Big data in transportation
[13]	2019	Y	N	Y	Y	N	N	Y	N	N	Frameworks to provide cloud services in vehicles have been discussed
[41]	2018	Y	N	Y	N	Y	Y	N	N	N	Machine learning was used to study VANET
[14]	2017	N	N	N	Y	N	N	Y	Y	Y	Enhancing Fog Computing with Vehicle Cloud Computing
[9]	2015	Y	N	N	Y	N	N	Y	Y	*	Application of data centers was discussed
[10]	2014	*	N	Y	Y	N	N	Y	*	*	Information-centric networking has been discussed
[42]	2014	Y	N	Y	Y	N	N	Y	N	N	

Table: Illustration of related works in the field. (Y): Detailed discussion, (N): Not discussed in detail, (*): Partially discussed

architecture, it's important to note that some key components may be needed for each type of application. For example, a data center for vehicle cloud computing would need ample cooling and power capacity, while a mobile app would instead require a lightweight hardware solution.

As with any type of cloud computing architecture, the goal is to ensure that all components are compatible with each other and will perform optimally under all possible operating conditions (temperature, humidity, etc.). For this reason, it's important to carefully analyze each component before embarking on any type of implementation project.

The vehicular cloud computing framework operates on three layers (Fig 1): the inside-vehicle layer, communication layer, and cloud interface layer. The inside-vehicle layer is the first stage of vehicular cloud computing, which monitors the health of the driver. The information obtained by sensors is sent to the cloud, where it is saved or used as input for various applications, including healthcare and environment recognition software. We assume that each car (is outfitted with an On-Board Unit (OBU) that has a navigational system and a map of the positions of the Roadside Unit (RSU). A vehicle's internal sensors and external ones (such as body sensors, internal sensors, inertial navigation systems (INSs), and driver behavior recognition, among others) are used to monitor a driver's health and mood and to identify his reflexes and intentions. The application layer, which is connected to the cloud and controls various software applications, uses the information gathered by the sensors to recognize driver health and environmental conditions.

cellular communications. The communication layer transmits data using 3G or 4G cellular networks, Wi-Fi, WAVE, and DSRC. An Emergency Warning Message (EWM) is generated and delivered to the cloud storage and other vehicles if a driver engages in risky driving behavior, such as going over the speed limit or experiencing a vehicle malfunction. (V2I), is in charge of transmitting operational data among vehicles, infrastructure, and the cloud, including the geographic location, velocity, acceleration, and direction of the offender.

The last level is known as the Cloud Interface Layer which has 3 components - cloud services, cloud infrastructure, and cloud applications layer. Cloud storage, cloud computation, and cloud infrastructure are among the components of the cloud infrastructure. Its main function includes storing information gathered by the inner-vehicle layer, as well as computations that are used to perform computation tasks such as driver behavior, health, and so on. The cloud infrastructure creates a network that enables real-time computation by providing cloud storage, cloud computation, and cloud infrastructure. Cloud services include network, storage, collaboration, and entertainment, among other things. A variety of application services are available as part of the application, including fuel monitoring, environmental and health monitoring, etc.

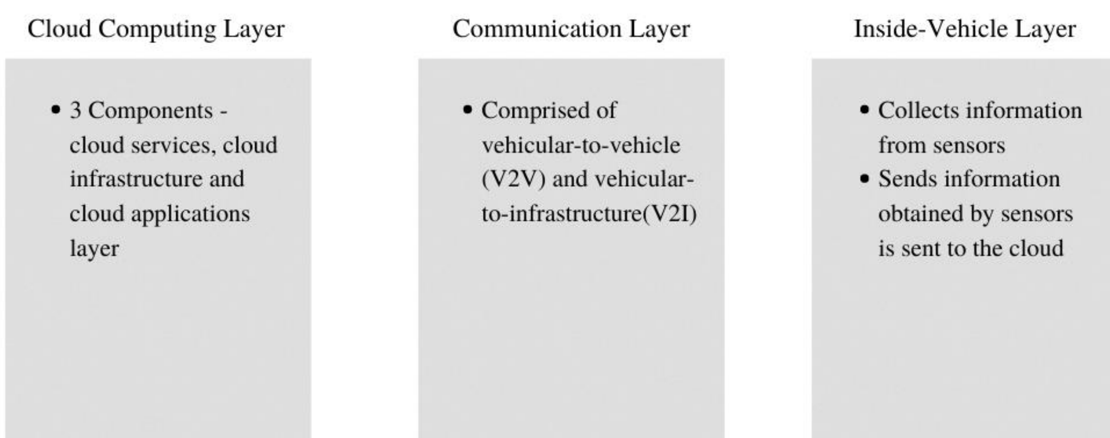

Fig 1: Diffferent layers in VCC architecture

The communication layer is comprised of vehicular-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems. V2V handles the data collection of driver behavior, health, and others through a variety of sensors inside and outside of the vehicle, including body sensors, and internal vehicle sensors, which measure temperature, among others. Data should be uploaded to the cloud for storage so that it can be used as input by applications and software for environmental and public health monitoring. A vehicle equipped with OBU devices such as radar, GPS, and others sends location data to the cloud via

A. *Different Proposed Architectures*

A proposed architecture can be found in [15]. In addition to addressing the heterogeneity of entities and networks, as well as fluctuating customer and vehicle demands, this system was able to handle the dynamic nature of vehicles entering or departing the network. Security concerns were also addressed. To encourage vehicle nodes to join the network, a prize-based method known as the secure token reward system was presented. Vehicles that offered their resources to the cloud in exchange for cloud services were rewarded with tokens as a form of incentive. The token reward system was maintained in the cloud to ensure the integrity of token transactions and efficient token management. In addition, service providers hired service provider managers to advertise their services, enter into contracts, validate proof of work, and issue reward tokens on their behalf. As a result, vehicle privacy is safeguarded and incentive-related messages' integrity and validity are guaranteed. Additionally, by using tokens to pay for services from the vehicular cloud in the future, vehicles can profit by pooling their resources.

An architecture that took into account the servers' resource limitations and the latency tolerance of computation tasks was proposed in the study [16]. The primary purpose of the architecture was to efficiently utilize the idle resources in the vehicle to support all the applications and services of VCC. An architecture for vehicular cloud computing is proposed to provide seamless and efficient vehicular cloud computing services. A remote central cloud server, several edge computing servers, several SDN controllers, several RSUs, a vehicular cloud, and several vehicles are included. When vehicles travel on a highway in opposite directions, some applications in a vehicle that has a lot of computing work can be moved to vehicles with little computing work using V2V communication mode. The vehicular cloud is composed of vehicular networks and cloud computing.

The paper [17] provided a complete evaluation of VCC. Using resources such as network as a service (NaaS), collaboration as a service (CoaaS), storage as a service (StaaS), and sensing as a service (SaaS), the authors developed a new two-layer architecture. Big data processing and management, along with privacy and security concerns, were not covered.

This paper [18], describes the vehicular cloud, a processing layer operating near end users on underutilized vehicle computing resources. Fixed edge computing nodes and a vehicular cloud are used to construct a vehicular cloud architecture. Mixed integer linear programming (MLP) has been used in this paper to optimize the allocation of computing requirements in a distributed architecture to minimize power consumption. The conventional cloud requires up to 84% more power than the distributed processing architecture. It minimizes power consumption by allocating computing resources in real-time with a heuristically optimized approach that approaches that of the MILP.

V. Characteristics of VCC

A. *Network as a Service (NaaS)*

While driving, some cars can have internet access while others do not. When necessary, vehicles having internet connectivity can supply or provide such service to other moving vehicles. It's referred to as "Network as a Service" (Naas).

B. *Storage as a Service (STaaS)*

Automobiles occasionally need extra storage because they have a limited amount of onboard memory to execute software. To enable other vehicles to use their storage pool to run their applications or provide services, vehicles having big onboard storage capacities can share it with them. It's called "Storage as a Service" (STaaS).

C. *Computation as a Service (CaaS)*

The computers on wheels become more and more potent with time. Therefore, vehicles could be viewed as the best supply of computation resources. Imagine a big airport parking lot chock-full of vehicles that are all parked. If we could make good use of all these extra computational capabilities, we could build a mobile data center with a lot of processing power. Computation-as-a-Service is now feasible as a result.

D. *Multiple Technologies*

The combination of multiple technologies is what makes the vehicular cloud so interesting. Choosing which technology to utilize to accomplish a certain objective is crucial here. For example, smartphones and other embedded gadgets may wish to free up their resources at certain times. They can therefore offload their traffic. [19]

E. *Pay As You Go*

Pay as you go is a payment model which charges users according to their usage instead of charging a prepaid fee. This enables higher scalability in VCC. Users can use the service according to their demands.

F. *Authentication Management*

The vehicular network provides authentication management among different vehicles which enables them to exchange information more freely.

G. *Security and privacy*

When sharing the same set of resources over a network, security and privacy are the two key concerns. Two things must be guaranteed when computing resources are shared among several users. First and foremost, owners' vehicles' security and privacy must be preserved. Furthermore, security and privacy must be provided to those that rent these resources. Technologies for virtualization solve both issues [20].

VI. Applications of VCC Using Big Data

A. *Traffic Environment*

A network architecture for heterogeneous vehicular communications that included service-oriented optimization was proposed in the study [21]. The research paper proposed a heterogeneous network model for IoV and service-oriented network optimization. In this network model, three key networking entities—vehicular cloud, heterogeneous communication, and smart utilization—served as clients. Network computations were performed at cloud servers to generate intelligent decisions on traffic-related data. Handoff-centric network communication was enabled in heterogeneous vehicular environments through the connection component. This study analyzed the service-oriented advantages of the network architecture by assessing multiple service-oriented metrics in real-world vehicular communication environments. The clients for the network model can be utilized to implement smart traffic services. Future problems and challenges in IoV environments were also mentioned.

An issue on intersection management was highlighted in [22]. Rerouting a simple urban intersection is impossible without affecting the intersection's management. It is possible to view the area from above in any manner. In special circumstances, such as traffic incidents and sporting events, more individualized route and traffic planning are necessary. Urban intersection management is a serious problem that cannot be solved by simple rerouting. In this situation, having a bird's-eye view of the area can aid in managing the situation. For example, a TMS that is frequently utilized in a city can alert drivers when they should not take a particular route because of congestion. As a result of following the recommended route, a congested alternative route would be created. The load balancing of road traffic is required in such a situation. Using the VCC, traffic control plans can be created that combine multiple clouds and process all information to ensure a balanced flow of traffic throughout a city [22].

[23] draws attention to the recent modifications made to VCC following the installation of onboard navigators. The Navigator Service Agency can collect information about traffic patterns and volumes in real-time from the Mobile Vehicle Cloud and offer specific route recommendations to vehicles to avoid route flapping. In “Mobile Cloud-enabled traffic management,” onboard vehicle navigators send time, GPS locations, and endpoints to an internet-based navigation server. The server assesses road segment capacities and delay produces a traffic load matrix and detects traffic patterns. It then generates incremental routes and sends them back to vehicles. When multiple directions are offered, the Navigator Server can balance the load among them. According to the on-board navigator, the driver's profile (aggressive or cautious) and vehicle type (gasoline or electric) can influence the route recommendations. The optimum, least-delay route is simulated by the vehicular cloud to achieve a quasi-steady state. This application demonstrates the value of interconnected cloud computing.

B. *Road Safety Message*

Road safety can benefit greatly from a vehicle cloud. Modern vehicles are equipped with sensors that gather data to monitor the road, ensure the safety of drivers and passengers, alert about road conditions such as risk, flood areas, congestion, temperatures, and speeds, alert about the condition of other vehicles, and evaluate the situation [24]. a vehicle with embedded sensors, cameras, GPS units, and other technology. The victim's speed, location, and direction are sent to the vehicle, surrounding vehicles, and the vehicular cloud in case there is any suspicious activity on the road. Additionally, it offers details on traffic issues, speed limits, weather, and other road conditions [9].

The research paper [38] suggests "HAaaS," a new cloud computing service for vehicles based on BANs (body area networks), to identify, track, and manage driver fatigue as well as to offer collaboration support for driver rescue. The two main factors that contribute to deadly traffic accidents are regarded to be fatigue and malaise while driving. A driver's ongoing health can be monitored using BANs without interfering with their regular daily activities.

C. *Urban Surveillance*

To study the potential use of cloud computing technologies to address geospatial issues in urban traffic systems, massive floating car data (FCD) processing for traffic surveillance in cloud computing environments was investigated in [25]. According to the results of the experiments, cloud computing technologies like Bigtable and MapReduce are useful for geospatial computing. Scalability and real-time computing performance can be greatly improved by utilizing the proposed big data storage, management, and parallel processing approaches. It has been determined that cloud computing is applicable and beneficial for three common geospatial computing tasks in urban traffic monitoring, namely querying FCD, matching FCDs on a map, and calculating road link speeds.

MobEyes is described in [26], which disseminates summaries about sensor data to support proactive urban surveillance in vehicles. It is a smart mob of autonomous mobile devices working in collaboration with VSN to make smart cities a reality. MDHP, which multiplies summary information collected by MDHP and opportunistically deploys mobility assistance, is the key component. The MobEyes evaluation results display that MDHP may be used to synchronize thousands of nodes with only a little overhead, while MobEyes' configuration offers the best balance between latency and completeness. Furthermore, the preliminary security solutions reveal that MobEyes is capable of defending against injected false data by attackers. These promising outcomes encourage further investigation.

D. Data center Formation

Driving around parking lots is a significant waste of computing resources. These underutilized processors can be shared or rented to interested parties with the permission of their owners. An example of a data center in mall parking lots was taken in [20]. The management of the mall should place an Ethernet cable in each parking space, and each vehicle will have an Ethernet connection. A driver who wants to rent his car's onboard resources must connect the Ethernet cable to the vehicle's Ethernet interface. A driver who rents his onboard resources to create a static VC must be rewarded by mall management.

The application of airport parking as a data center was explained in [27]. Vehicles left in airport parking lots are a resource that can be used to create a VCC data center. When people travel, they abandon their vehicles there. It is possible to profit from these cars by converting them into VCs. For example, airport administration may offer electrical power, storage, or Ethernet connectivity if they want to lease their resources to those who want to rent them. A VC participant's arrival and departure hours will be shared. The management of the airport can schedule shared onboard resources using this information. Long-term parking spaces and shared travel arrangements will be widely available, reliable, and long-term to achieve this.

[39] describes a data center made out of numerous automobiles parked in a long-term parking area of an international airport. The vehicles are connected to the airport's main server via Ethernet and are connected to conventional power outlets. Parking lots are viewed as a collection of cloud nodes that can act as a data center. They used variations in the arrival and departure rates of the parking lot to estimate the anticipated number of automobiles there and then scheduled resources and assigned computational jobs to heterogeneous vehicles in the VCC. They make static assumptions and calculate the capacity using a queuing model.

E. Traffic Lights Management

Big data collected from vehicles can help in solving traffic-related issues. [20] suggested a system in which vehicles stuck in traffic would share their resources with the municipal authorities. The data will guide the authority in rearranging traffic lights so that the jam can be cleared up as soon as possible. These cars will provide computational power to a municipal authority to dissipate the traffic jam as soon as possible. Although the municipal authority has the code and the authority to run it (the rescheduling program), they do not have enough computational infrastructure to do so. Drivers will be willing to let the municipality use their car's computational power for the public good, which is in line with their interests.

The research paper [40] proposed a user-driven Cloud Transportation system (CTS), which includes data collection, filtering, modeling, intelligent computation, and publishing. It uses a user-driven crowdsourcing strategy to collect big data from users for traffic model construction and congestion prediction.

F. Disaster Management

An advantage of VCC is that it provides instant communication to other vehicles or base stations or authorized authorities in disaster management. Vehicles send or broadcast messages to all available resources, such as other vehicles, base stations, etc., in case of an emergency.

G. Intelligent parking management

In [29], a cloud-based intelligent parking service was suggested. Each car has a small CPU and a short-range transmitter already installed. Zigbee, Bluetooth, and infrared devices, for example, may all be used as transceivers at a low cost. A wireless transceiver and processor are enlisted into an event data recorder (EDR). A parking lot that utilizes Wifi, infrared sensors, and parking belts to identify and penalize off-parking vehicles were built. When a vehicle enters a parking lot seeking a reserved space, the entrance booth will verify it. Once the parking spot has been verified, information-based guidance can be provided to the vehicle to locate it. The infrared device, lights, and parking belt will collaborate to prevent and penalize off-parking. Infrastructure to publish advertisements from the parking lot was also designed. Advertisements can be posted from the parking lot infrastructure, which includes wireless transceiver towers and transceivers that are mounted on the roadside. The computer center constantly monitors the status of the parking lot, and the status information can be broadcast by the wireless tower.

In [28], a parking management system was suggested. The VC will allow vehicles to reserve parking spaces. The cloud will hold all parking-related data, doing away with the need for central administration. It is possible to move parking requests from various physical places to the best parking lots.

H. Crossroad Accident Alerts

Drivers can request this feature to warn them of potential collisions at intersections when driving in adverse weather conditions such as heavy storms, fog, or icy roads. Since infrastructure such as a tall building can include high-precision radar to detect vehicle collisions, this infrastructure will be able to detect accidents across an intersection. Every time this infrastructure scans an intersection, an intelligent algorithm will be applied to each result to estimate the risk of a collision [28]. A cloud model was also proposed in this paper. Several grids are linked to the proposed model. Grids are used to divide up cities or busy areas. Each grid has a cloud-based virtual machine attached to it. When the grid is overloaded, the virtual machine could request more resources from the cloud. A sparse grid's corresponding virtual machine can request more cloud computing, storage, and communication resources when there are fewer virtual machines in the grid. These resources can be taken from a virtual machine that is not in use but is connected to a grid with lots of traffic. As a result, the cloud can keep track of all of the city's traffic. In the virtual machine, smart parking and congestion control services can be designed and optimized specifically. In particular, a collision warning service may be tailored and optimized. The mobility information of all the vehicles at an intersection might be collected and sorted to detect vehicles that come close to each other. A cloud collision warning system, even if it is more inexpensive, may be of benefit to vehicles that do not have radar cruise control systems.

VII. ISSUES AND THEIR SOLUTIONS

A. Security Issues

Several security problems affect VCs. [28] identified issues such as establishing trust relationships between numerous parties as a result of intermittent short-range communications, authenticating mobile vehicles, scaling, and a single interface. The proposed approach included the use of VM (Virtual Machine) such as Amazon's E2C. To gain trust relationships, an infrastructure built by the transportation agencies was proposed. This infrastructure would be built to store security key pairs and verify their authenticity. Vehicles could access the VC through this infrastructure, which would store key pairs in tamperproof devices. The infrastructure would handle a large number of accesses within its transmission range. Trust relationships can be scaled because the infrastructure is connected to other infrastructure through fixed networks. A geographic location-based security mechanism was designed to ensure physical safety in addition to traditional precautions to enable authentication and confidentiality. The geographic location key encrypts messages and specifies a location for decrypting the message. This guarantees physical safety because a car must be physically present in the decryption location to decrypt encrypted text.

B. Virtual Machine Management

VCC provides vehicles with various resources that are typically underutilized. VMs may be hosted on these underutilized resources to help cloud service providers (CSPs) deliver various services and increase their utilization [30].

A vehicular cloud is a data center with unstable physical hosts. Therefore, managing virtual machines in vehicular clouds is difficult. When a vehicle leaves the range of any RSUs (Road Side Units) or when a handover occurs between two RSUs that are within range of a vehicle, VM migration may occur [31]. Refaat et al. in their paper [32] suggested a VM migration mechanism to address this problem. Starting with the nearest vehicle, the VM migration algorithm chooses a destination vehicular node. If the VM cannot be moved to the destination node within a predetermined time limit or if there is not enough space at the destination node to accept the VM, the VM is moved to the destination vehicular node.

C. Lack of Infrastructure for Vehicular Cloud Computing

As we have mentioned earlier, the emergence of IoT-enabled cars has necessitated the need for vehicular cloud computing. However, there is a lack of infrastructure around the world to support this technology. This is one of the biggest challenges in vehicular cloud computing. To build a robust infrastructure, the government needs to invest heavily in the development of communication towers and internet service providers. Apart from that, they also need to introduce new standards and regulations regarding vehicular cloud computing.

Achieving large-scale vehicle communication using emerging technologies such as 4G/5G telecom technology is feasible. IEEE 802.11p[43] may be used to create seamless network connections for reliable and rapid communication by combining it with other access networks such as cellular networks. Heterogeneous vehicular networks that rely on Wi-Fi, WiMAX, 3G, LTE, and LTE advanced networks are examples of such networks. These networks are utilized in V2cellular clouds, which connect vehicles with commercial clouds via cellular connections [22].

D. *The Need for Standardization in Vehicular Cloud Computing*

There is a dearth of standards in the field of vehicular cloud computing. Manufacturers face difficulty in choosing the right communication protocol and data analytics tools that can be easily integrated with their system. This scenario is also slowing down the development of new standards regarding vehicular cloud computing. The lack of standards in this field has become more apparent with the emergence of 5G technology. Vehicles can be seamlessly integrated with 5G networks, and manufacturers are already working towards this. However, there is no standard in place that can help them adopt 5G technology. For seamless inters-operation, decision support, developing accountability measures, standardization, legislation, and even local and national policy-making, effective operational policies are required [33].

E. *Limited Bandwidth and Storage*

While the advances in the field of cloud computing are noteworthy, it has also led to an increase in the demand for bandwidth and storage. This has, in turn, led to an increase in the costs associated with vehicular cloud computing. Vehicles are getting smarter every day, and manufacturers are using innovative technologies to create a state-of-the-art infotainment systems. As a result, they are also increasing the demand for bandwidth and storage. Effective exchange of big data across vehicles is a challenging issue. As we have already mentioned, vehicle data is stored in the cloud and can be accessed through a mobile app. Hence, it is important to ensure that the cloud service providers have enough bandwidth and storage capacity to store big data.

A Bayesian coalition scheme was introduced in [34] to reduce energy consumption. It used the concepts of game theory. By balancing loads during virtual machine resource sharing, they investigated how to utilize computer resources effectively.

In cloud-enabled vehicle networks, various SPs can cooperate using a model-based coalition game proposed in [35]. A virtual resource network comprises cloud SPs, which can remotely operate mobile applications on powerful servers. Resource cooperation can be encouraged through the virtual resource network, which provides reserved bandwidth and computing resources for mobile apps. A coalition game approach is used to speed up the coalition formation process.

The paper [36] proposes an architecture in which roadside clouds can support a large number of vehicles by allowing them to pool their computing, storage, and bandwidth resources. This is accomplished by integrating cloud computing and VCC. The vehicular cloud, roadside cloud, and central cloud are all part of the proposed architecture. In this cloud-based vehicular network, we allocate cloud resources and migrate virtual machines optimally. A game-theoretic approach is used to optimally allocate cloud resources. This approach reservations resources to optimally handle virtual machine migration resulting from vehicle mobility.

F. *Data Transmission Latency in Vehicular Clouds*

While most of the challenges in vehicular cloud computing are related to its adoption, there is one challenge that is related to its functionality. This challenge pertains to the latency or lag time in the big data transmission between the car and the cloud. While this might not seem like a big issue, it can be problematic in certain situations. For instance, when a car is involved in an accident, the medical authorities need to know the medical history of the driver. They need to know if the driver is allergic to certain drugs, if he or she is pregnant, if he or she is taking certain medications, and so on. However, if the data related to the medical history of the driver is stored in the cloud, the medical authorities will not be able to access it immediately. This is because of the lag time in big data transmission. They will likely get the details of the driver only after the car is towed to the nearest garage and connected to the internet.

In [37], a learning-based task offloading framework was created using the multi-armed bandit (MAB) theory. In this instance, the cars offloading their responsibilities are referred to as task vehicles (TaVs), while the vehicles delivering services are referred to as service vehicles (SeVs). This framework allows vehicles to learn the potential task offloading performance of their nearby SeVs, which have an excessive amount of computing power. This framework works to minimize the average offloading delay. To reduce significant signaling exchange overhead, task offloading decisions are made distributedly, i.e., each TaV makes its task offloading decisions.

VIII. Discussion and Conclusion

The challenges in vehicular cloud computing are mainly due to the lack of infrastructure and the absence of standardization. However, these challenges can be addressed by investing heavily in the development of communication towers and internet service providers. The adoption of big data can transform the car from just a device for transportation to a mobile command center and entertainment hub. It is also important to ensure that the data related to the operation of the car is stored securely in the cloud. In this paper, we discussed the applications, challenges, and solutions of big data in VCC. We also discussed the proposed architectures of VCC by different authors. These architectures have been developed to further develop the application of VCC in different fields.

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