Vehicular Cloud Computing (*VCC*)

Juwairiah Saleem, Naveera Jamil, Mahwish Naseem,
Ambreen Jahan and Sadia Javed

Department of Computer Science, Jinnah University for Women,
Karachi, Pakistan
juwairiah.saleem1996@gmail.com, naveerajamil18@gmail.com
mahwishnaseem17@gmail.com, ambreenjahan18@gmail.com, sadi0921@gmail.com

Abstract- During the last decade, Vehicular Ad-hoc Network (VANET) research area has been a prime focus for the researchers and developers owing to its important applications, including efficient traffic management, road safety, and entertainment. Vehicles are increasingly equipped with extensive resources in terms of computing power, data storage, and sensing capabilities and these resources are typically underutilized, due to the constrained service and resource management models. With the emergence of highly developed vehicular applications, the issues such as low latency, security, quality of service and uninterrupted services have also been increasing which demands for the powerful communication and computation facilities. To satisfy the requirements of VANETs, Vehicular Cloud Computing (VCC) has come up as a solution. The research community needs to take these issues into consideration and they should be solved for the continuance of the development in this area. Vehicular Cloud Computing (VCC) is predicted to play a considerable role in the development of smart traffic management and in emerging Internet of vehicles. This research paper provides insights into the most recent technology of VCC and discusses applications, issues and challenges with their appropriate solutions and the limitations associated with those solutions.

Keywords: VANET, Issues of VCC, Solutions of VCC, Limitations of Vehicular Cloud, Internet of Vehicles, Traffic Control System, Location, GPS issues, Parking Management System.

I. INTRODUCTION

A unique concept of vehicular cloud (VC) has emerged recently, as an effective technology where a number of automobiles make a cloud to share their resources (for instance, computing storage, power, and bandwidth). The network of vehicles carries out the automobile applications in a collaborative manner. With the use of VC, each vehicle can do many tasks requiring resources, e.g., Network as a Service (NaaS), Data as a Service (DaaS), and Computing as a Service (CaaS) [1] for surveillance device, driving and other services. A car with dynamic flexibility and mobility, which is considered as the most important characteristic of vehicles, may also be used to reduce the excellence of VC services to the users. As the resources of the car can no longer be constantly provided to carry out specified tasks, it can affect the VC. Vehicles give rise to more and more essential demand of computing and detecting resources for drivers for their better safety and to help them avoid the accidents and traffic jams [4]. Those sources may be controlled by means of defining a mobile vehicular platform wherein numerous utilities may be created and shared amongst all cars on the roads. The mobile vehicle cloud has unique but complementary functionalities with respect to the internet cloud [5]. The target automobile cloud applications are able to sense the environment and set up the relation between its properties and results. The results help the drivers and the whole community, in terms of safe navigation, smart traffic management, locally relevant records and entertainment [7].

In the last few years, Cloud Computing (CC) service has been extensively used internationally. Meanwhile, studies on Vehicular Ad-hoc Network (VANET) have progressed a fair bit [10]. The issues associated with VCC have been discussed in this paper, providing the possible solutions to those problems and discussing limitations of the provided solutions [11]. The most common applications of the VCC have also been pointed out.

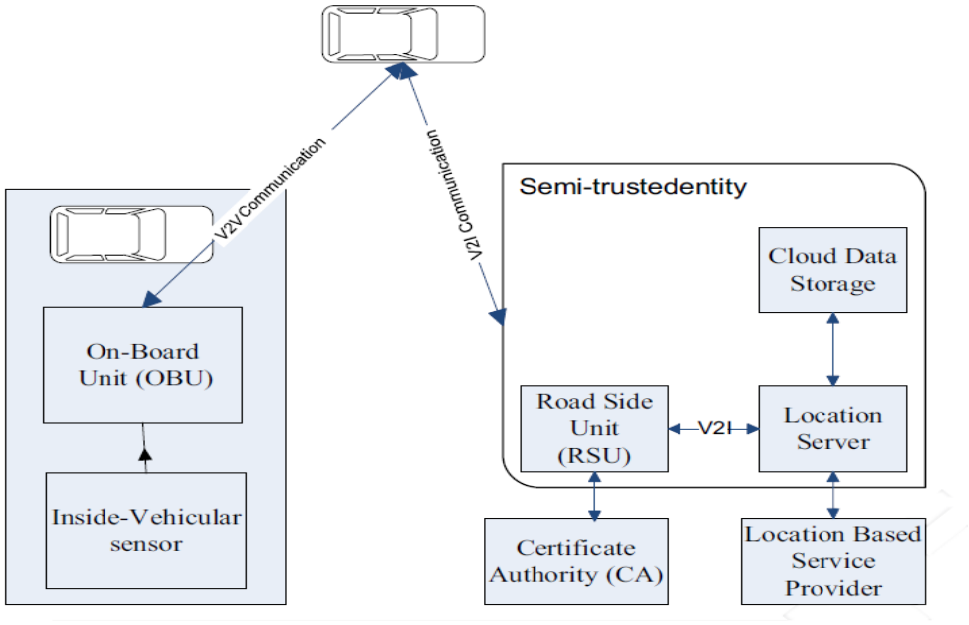

Figure 1: Block Diagram of Vehicular Cloud System

II. APPLICATIONS

A. *Parking*

- *Intelligent parking management:*

  Drivers will be able to reserve parking area to park the vehicles by using VC [2]. All the information of parking will be accessible on cloud without central control [8][10].

- *Managing parking facilities:*

  Automated parking management helps in finding proper parking places in the area [1]. Nowadays, drivers are capable of finding suitable parking place by using their mobile applications (e.g. ParkMate, ParkME, SmartPark etc) [3].These applications have various disadvantages, such as: need for internet connection and limited coverage of the world. VC services can help improve the VANET-based parking [4][5]. Cloud of vehicles (VC) in specific area will manage data on real time accessible parking places and direct the drivers to the best suitable parking spots.

B. *Traffic*

- *Dynamic traffic light management:*

  These days, the number of vehicles on the road is increasing day by day, and the problem of traffic jams wastes a considerable amount of human energy and valuable time [1]. These issues can be solved by assigning the resources on merit rather than pre-allocating resources within a few resourceful users [5]. VCC is capable of providing an effective and efficient way to combat overcrowding in the traffic by searching an autonomous solution without waiting for the response [7] [8].

- *Optimizing traffic signals:*

  Traffic signal set the green phase length and signal cycle length [1]. System of signal optimization is presently happening offline at both the inaccessible connection and the passage level [2]. The drawback is that this system does not work well with undefined modifications in traffic condition [7] [8].Therefore VCs can increase the system of signal show by making effective use of a vehicular network.

C. *Safety*

- *Safety applications:*

  Applications associated with life-threatening situations e.g. clash prevention and adaptive cruise control need strong defense protection, from close environmental safety risk even. [2] [8] [10].

- *Vehicle maintenance:*

  Cars obtain updates of software from cloud resources when manufacturers of vehicles upload the latest version of software [2] [6].

- *Road safety message:*

  Vehicles, nowadays have inserted detecting devices for safe and expert processing [1]. Therefore, vehicles detect the node and a Vehicular Cloud (VC) can form effective network with a big portable sensor network. Vehicles question the sensors of further vehicles in nearby vicinity to expand the loyalty [5], and get an evaluation of the possible road risk ahead [8] [10].

D. Alert

- *Easing frequent congestion:*
  Some drivers try to find detours and alternative routes using native roads [1]. Taking decision during diving is difficult, mostly when various vehicles struggle to travel in the same direction and the capacity of road is compromised hence causing deadlocks. The advisory of traffic and modern ITS system are both slow to resolve the problem of traffic and have no improvement plan as such [3] [6]. Therefore buses in the district will be capable to compute the effect of the local road and the causes of congestion in the flow of traffic which can help control the congestion [7].
- *Accident alerts at intersections:*

  In difficult driving conditions such as snow, heavy rain, fog etc [2]. Drivers can utilize this facility to make them aware of potential intersection and accidents. This group will protect the intersections and often inspect them. A smart process will be applied to each inspection outcomes to forecast the probability of potential hazards [6] [10].
- *Planned evacuations:*

  Under certain disaster, for example, storms or tsunamis, VCs will be resources to aid successful evacuation ensuring safety of the vehicles [2] [5] [8].
- *Road condition sharing:*

  Conditions of roads for example overflowing area and ice storm in the roadway can be shared in VCs. Drivers will be warned if there are hazardous road conditions[2] [6] [9] [10].

Table 1: Applications of Vehicular Cloud Computing

Categories	Sub-Categories	Contributions
Parking	**Intelligent parking management**: Drivers will be able to reserve parking area to park the vehicles by using VC. All the information of parking will be accessible on cloud without central control.	[2], [8], [10]
	Managing parking facilities: Automated parking management helps in finding proper parking places in the area.VC in specific area will manage data on real time accessible parking places and direct the drivers to the best suitable parking spots.	[1], [3], [4], [5]
Traffic	**Dynamic traffic light management:** VCC is capable of representing a further effective and efficient way to resolve the overcrowding by providing the necessary resources from the accessible vehicles contributing in the traffic and including them in searching an autonomous solution without waiting for the response.	[1], [5], [7], [8]
	Optimizing traffic signals: VCs can increase the system of signal show by making effective use of a vehicular network.	[1], [2], [7], [8]
Safety	**Safety applications:** Applications associated with life-threatening situations e.g. clash prevention and adaptive cruise control need strong defense protection, from close environmental safety risk even.	[2], [8], [10]
	Vehicle maintenance: Cars obtain updates of software from cloud resources when manufacturers of vehicles upload the latest version of software.	[2], [6]
	Road safety message: Vehicles, nowadays have inserted detecting devices for safe and expert processing. Therefore, vehicles question the sensors of further vehicles in nearby vicinity to expand the loyalty, and get an evaluation of the possible road risk ahead.	[1], [5], [8],[10]

Alert	**Accident alerts at intersections:** In difficult condition of driving such as snow, heavy rain, fog etc. Drivers can utilize this facility to make them aware of potential intersection and accidents.	[2], [6], [10]
	Easing frequent congestion: Buses in the district will be capable to compute the effect of the local road and the causes of congestion in the flow of traffic which can help control the congestion.	[1], [3], [6], [7]
	Planned evacuations: Under certain disaster, for example, storms or tsunamis, VCs will be resources to aid successful evacuation ensuring safety of the vehicles.	[2], [5], [8]
	Road condition sharing: Conditions of roads for example overflowing area and ice storm in the roadway can be shared in VCs. Drivers will be warned if there are hazardous road conditions.	[2], [6], [9], [10]

III. ISSUES, SOLUTIONS AND LIMITATIONS

A. Secure Localization:

For Vehicular Cloud Computing (VCC), it is very necessary for a vehicle to use its current location in order to communicate to the other vehicle. For instance information like congestion avoidance, current traffic status, alerts etc must use real time locations [1]. Therefore vehicle must have GPS device in order to send current data. If vehicles don't have any GPS it would be difficult to track them [15].

Solution:

Every vehicle must have tampered proof GPS so that the vehicle can send information and communicate with the other vehicles. However, sometimes, the GPS signals are not accurate due to some obstacles in the path of the signals [1]. Plausibility Checks is another key method to ensure positional trustworthiness and reliability [17]. If the drivers are using GPS on a battery operated device, there are chances of drained out battery causing failure in connectivity [18] [19].

B. Authentication and Privacy Issue:

In VCC, authentication of users and messages must be verified so that Vehicles and RSUs (Road Side Users) authenticate themselves [1]. If the system is attacked by a hacker, their all activities and communication can be accessed by the attacker [15], [20].

Solution:

To avoid this issue pseudonyms should be used so that they can't be tracked. In case of any crimes perpetrated by the vehicles, it will be hectic and time consuming to check all the registered vehicles and driver's real names [15]. The next solution is to use Identity Based Cryptography for protection of the users and the vehicles. In which two drivers can identify each other through signatures prior to exchanging messages. In Identity based cryptography, the keys are generated by PKG (Private Key Generator) [20], [22], the PKG can decrypt messages and generate digital signature for the user without any authentication [23]. The other solution is to use Attribute Based Encryption which is more secure than Identity Based Cryptography. To give a complete access to key requester, the key generator does not know about the private keys picked by the key requester [27].

C. Confidentiality Issue:

Another issue in VCC is the confidentiality issue [1]. In VANET, the communication and messages between vehicles are exchanged publically apart from the users' information [23]. So, the users never know that their messages are read by authorized person or not.

Solution:

To solve this, region based RSUs must be introduced so that when vehicle enters in a particular region it must be registered by that region RSUs [15] whereby each vehicle of a region is issued a symmetric public key. However, if the region in which RSUs will be installed is far from the internet infrastructure, the cost of installation will increase accordingly [16]. Another way to solve this problem is to use self-organizing geographical location [24]. All the vehicles that lie in a particular geographical location, must establish a group communication. They select a group leader which distributes symmetric public key. However, the increase of scalability in self-organizing decreases its behavior, because the necessary state information cannot be retrieved [28].

D. Communication Security Issue:

VCC cannot be handled without the cloud computing. Vehicles in a VCC environment have to communicate with the cloud in order to process and store the information in a cloud database [25]. But there are various security issues of the network like traffic tampering, jamming attacks etc.

Solution:

Digital signatures like elGamal Signature Scheme, Elliptic Curve Cryptography, Group Signature must be used to secure the communication issue [1]. For the verification of digital signatures, it takes considerable time. So the speed of communication from one vehicle to another will be considerably impacted [26].

E. Data Security Issue:

Data exchanged contains valuable piece of information for everyone [1]. There are several types of data attacks including Packet Dropping, Misrouting, corruption in packet content etc.[15] For the security of data it is to be ensured in VCC that sensitive data must not be access by an unauthorized user[29].

Solution:

When data is shared amongst users across the network, identify the compromised node and reorganize the network and exclude the compromised nodes [29].

Table 2: Issues, Solutions and Limitations

S.no.	Issues	Solutions	Limitations	Contributions
1.	**Secure Localization**	**Tamper proof GPS**	Sometimes, the GPS signals are not accurate due to some obstacles in the path of the signals.	[1],[15],[19]
		Plausibility Checks	If you are using GPS on a battery operated device, there are chances of drained out battery causing failure in connectivity.	[1],[15],[17],[18]
2.	**Authentication and Privacy Issue**	**Pseudonym**	In case of any crimes perpetrated by the vehicles, it will be hectic and time consuming to check all the registered vehicles and driver's real names.	[1],[15],[20]
		Identity Based Cryptography	In Identity based cryptography, the keys are generated by PKG (Private Key Generator), the PKG can decrypt messages and generate digital signature for the user without any authentication.	[1],[15],[23],[27]
		Attribute Based Encryption	To give a complete access to key requester, the key generator does not know about the private keys picked by the key requester.	[1],[15],[22]
3.	**Confidentiality Issue**	**RSU's for a Region**	If the region in which RSUs will be installed is far from the internet infrastructure, the cost of installation will increase accordingly.	[1],[15],[16],[23]
		Self Organizing Geographical Location	The increase of scalability in self-organizing decreases its behavior, because the necessary state information cannot be retrieved.	[1],[15],[24],[28]
4.	**Communication Security Issue**	**Digital Signature**	For the verification of digital signatures, it takes considerable time. So the speed of communication from one vehicle to another will be considerably impacted.	[1],[25],[26]
5.	**Data Security Issue**	**Identifying the compromised nodes**	This process is quite time consuming.	[1],[15],[29]

IV. CONCLUSION

The idea of VCC came forward from the combination of effective fixed vehicle sources, progress in network mobility; cloud computing and ubiquitous sensing [12]. Researches have proved that just as the VCC's importance can't be neglected, the issues associated with it cannot be ignored as they pose threats to the security and privacy of data exchanged. The research for the paper gave us a chance to put forward the details about VCC including numerous interesting applications, security and privacy issues, Key control techniques and appropriate solutions to these issues. The limitations of the proposed solutions have also been discussed and mentioned. We have covered a complete taxonomy of vehicular networking, VCC and a comparative study among CC and VCC to elaborate further on the merits and demerits of each of these technologies. We have also identified efficient traffic control, cloud communication machines and interoperability among the vehicular cloud [14].

In a nut shell, VCC is an attractive solution which could serve the drivers and their vehicles with valuable information to ensure smooth and uninterrupted traffic as well as ease of parking through exchange of information. However, like all solutions, it has its own share of issues, limitation and risks that need to be addressed prior to putting it in use.

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