The Role of Vehicular Cloud Computing in Road Traffic Management: A Survey

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Abstract. The vehicular cloud computing (VCC) is an emerging technology that changed the vehicular communication and underlying traffic management applications. The underutilized resources of vehicles can be shared with other vehicles over the VANET to manage the road traffic more efficiently. The cloud computing and its capability of integrating and sharing resources, plays potential role in the development of traffic management systems (TMSs). This paper reviews the VCC based traffic management solutions to analyze the role of VCC in road traffic management. Particularly, an analysis of VANET based and VCC based TMSs is presented. To explore, the VANET infrastructure and services, a comparison of VCC based TMSs is provided. A taxonomy of vehicular clouds is presented, in order to identify and differentiate the type of vehicular cloud's integration. Potential future challenges and their solutions in respect of emerging technologies are also discussed. The VCC is envision to play an important role in further development of intelligence transportation system.

Keywords: VANET · Vehicular cloud computing · Traffic management systems · Traffic flow control

1 Introduction

The Vehicular ad hoc network (VANET) [1, 2] is a subset of MANET. But VANET behaves differently because VANET has different properties like known routes, high speed and mobility [1–5]. VANET enables vehicles to communicate and share data wirelessly. The increasing number of vehicles on the road increasing the traffic load on transportation infrastructure, thus, making the driving unsafe and uncomfortable. The existing transportation system need to be modified, in order to make traffic safe [3] and efficient. It means new traffic management solutions are required to handle the challenge.

Usually, when congestion happens, the road infrastructure seems too small to handle the larger demand. Nowadays, the vehicle manufacturers wish to provide all capabilities to improve road safety and infotainment services. In order to provide these services, intelligent transportation systems (ITS) [4–6] support different traffic applications. These applications includes traffic safety, non-safety and flow efficiency applications. VANET support these traffic applications and it is main part of ITS.

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The vehicle manufacturers, research communities and government authorities are making their efforts toward creating a standardized platform for vehicular communications. Consortium are formed, by multinational companies to increase efforts to tackle the problem of traffic management.

It is worth mentioning that recent improvements in software, hardware and communication technologies empower the design and development of cloud computing technology. The capability of cloud computing like dynamic resource integration and sharing, plays an important role in the development of emerging TMSs. The improved data and resource sharing among vehicles leads to VCC. VCC provides access to the dynamically configurable and integrated vehicular underutilized resources. This make the numbers of new applications based on VCC to be developed in order to provide various services to the drivers and passengers [6]. The VCC gives birth to a new pool of services which is a paradigm shift in the development of vehicular TMSs. This influences the development of new TMS potentially. An analysis of the role of VCC is provided in Sect. 3.

Now, various resources of vehicles are available to the end users [7]. The traffic data processed over data centers or over remote server, to provide information back to vehicles and passengers to control the movement of vehicles. Communications in VANET are generally classified into vehicle-to-vehicle (V2V) and vehicle-to-Infrastructure (V2I) communication. Vehicle communicate with other vehicles and Road Side Units (RSU). RSUs are intelligent devices, process data and send information to other RSUs as well. Our contributions in this paper includes;

- Reviewing emerging VANET traffic management applications
- Services and infrastructure based analysis of VCC based traffic applications
- A basic taxonomy of vehicular clouds
- Potential future challenges and issues

The rest of the paper is organized as follows. The review of VANET based TMSs and comparative analysis are described in Sect. 2. The analysis of VCC based traffic management systems, vehicular cloud's taxonomy and comparison are discussed in Sect. 3. Section 4 gives the future challenges of traffic management and finally the conclusion is drawn in Sect. 5.

2 Traffic Management Based on VANET

The VANET is the fundamental part of ITS which transforms the way of driving on the road. Today, driving on the road is more secure, safe and comfortable. Many efforts are made to reach these objectives, however, VANET's drawbacks such as high mobility of the vehicle and security issue does not allow researchers to meet these objectives [36]. The mobile internet and social networking in vehicles brings people and drivers more close to each other. Today, cars and vehicles are furnished with communication, computing and sensing devices, and universal networks such as internet. The driving experience is more enjoyable, comfortable, safe and environmental friendly than past but there are a lot of new paradigms to explore. The on board computing abilities, the vehicles are furnished with, are not fully utilized by the applications mentioned above.

The TMSs are broadly divided into three categories V2V (infrastructure-less), V2I (infrastructure-based) and Hybrid. Further, on the basis of control strategy TMSs are categorized as adaptive and predictive. Table 1 shows the classification of recent TMSs.

Table 1. Classification of TMSs

VANET infrastructure	Traffic flow control strategy	
	Adaptive	Predictive
	Use a control strategy that adapts changes based on actual traffic demands	Use data analytics to determine potential future locations of congestion and traffic flow
V2V	[8–10]	[11]
V2I	[12, 13]	[14–16]
Hybrid	[17–19]	[20–22]

TMSs make use of few common schemes like traffic estimation (density), historic traffic information, future predictions, and more recent schemes like platooning (grouping). The traditional traffic lights uses static time limits at the traffic signal intersections. The dynamically traffic lights can be developed based on the number of vehicles in a lane and by giving priority to emergency vehicle to surpass the signal quickly [23].

In order to cater broadcasting storm, traffic information has to be limited in detail [24]. This can be done by exploiting V2V communication, by apply data aggregation techniques to limit bandwidth use and maintain scalability. To avoid the overlapping of aggregates for the same area, there must be a scheme. A better aggregation scheme exploit V2V communication more effectively. One of the solutions is formation of groups of connected vehicles (clusters) [25]. The formation of cluster should be done intelligently that avoids collision among clusters. The most appropriate V2V scheme must calculates and detects the level of congestion in distributed way without the support of any infrastructure and additional information [8]. The adaptive broadcasting scheme should be utilized which gives awareness to at micro level. The congestion quantification is good for low VANET penetration rate.

ITS provide several features like Multi-input and multi-output capability which can be utilized to form multi-objective function. Such, multi-objective function take multiple parameters to provide congestion control, vehicle re-routing and planning. As the system uses the feedback information measured from the real-time vehicular traffic, it works in a closed loop manner. Factors such as vehicle velocity, vehicle position and distance between vehicles as well as between vehicles and RSUs greatly affect the performance of TMSs. These factors also affect the reliability and delay of links.

3 Vehicular Cloud Computing in TMSs

An important property of cloud computing is that no investment is needed because instead of buying, resources and services are rented on demand. Vehicular cloud computing services of a particular cloud are dependent on the purpose for which the cloud is formed [26, 27]. Generally, vehicular clouds provide services [28] such as platform as a Service (PaaS), Infrastructure as a Service (IaaS), Software as a Service (SaaS), Application as a Service (AaaS), and storage as a service (STaaS). The explanation of these services is already there in literature like [26–29].

Vehicles can subscribe cloud provided services on demand. By connecting OBUs through wireless networks such as 3G/4G-LTE and Wi-Fi networks, users can obtain almost unlimited computing power and storage from the cloud. The VCC improves the collection, processing and dissemination of traffic related data. VCC integrates and coordinates the available vehicular resources and enables the road traffic management in better way. Which reduces risk of life, cost and time.

3.1 Taxonomy of Vehicular Clouds

The vehicular clouds have different types. On the basis of purpose for which a TMS form a cloud, the vehicular clouds are classified into two main classes named as V2V clouds and V2I clouds as shown in Fig. 1. The classification is done on the basis of services for which cloud is to be formed, infrastructure used and involvement of third party clouds (Internet and other commercial clouds).

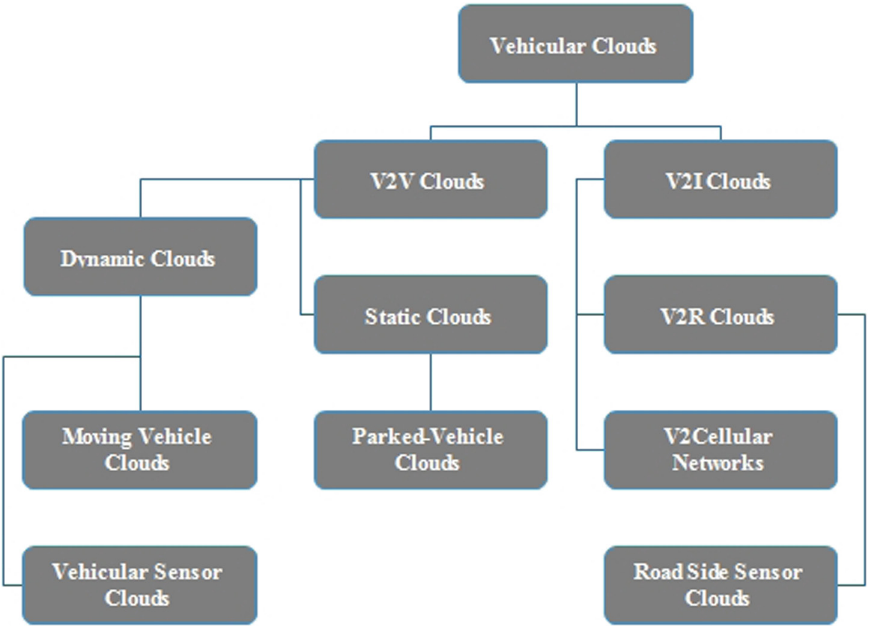

Fig. 1. Taxonomy of vehicular clouds

V2V Clouds. V2V clouds are formed by exploiting V2V type of communication infrastructure (DSRC). Dynamic clouds are formed by vehicles on the roads or in the parking lot, for typical service needed by underlying TMS. Like vehicles on the road form cloud to know the status of each other and to make intelligent decision regarding rout planning. Same as the vehicles in the parking lot provide storage and processing services named as static cloud.

These type of clouds rely on V2V communication infrastructure. Vehicular sensor clouds are formed for the purpose of vehicle or road traffic monitoring. The sensors within the vehicle gets vehicle related data, other vehicles in the cloud can take these services. For example a vehicle for behind the intersection can send query to the camera of a vehicle which is nearer to the intersection to get a real time picture of intersection. These type of services can be given through vehicular sensor clouds by utilizing sensors those are associated with vehicles.

V2I Clouds. In this type of vehicular clouds, the vehicles make use of road side infrastructural communication networks. These communication networks include DSRC, WIFI, 3G/LTE. If vehicles in cloud rely on RSUs for control information then the cloud called as V2R clouds and if vehicles in cloud rely on 3G/LTE networks then the cloud called as V2Cellular cloud. Both of these cloud types have their own pros and cons and it depends on the purpose for which clouds are being formed. As for larger geographical area the V2Celluar clouds are useful and for smaller coverage area V2R clouds are better. RSUs, intersections and special entry points are often equipped with traffic monitoring sensors, radars and cameras.

These sensor can work together to form a cloud to share real time information with TIS and vehicles. These type of clouds are known as road side vehicular sensor clouds. The services like participatory sensing and cooperative sensing are the main purpose of these clouds.

The identified types of vehicular clouds collaborate and integrates with each other in order to provide different services to users. Cloud cooperation and collaboration is emerging concept which may lead to new type of services.

3.2 Comparative Study of VCC Based TMSs

A comparison of some VCC based TMSs is presented in Table 2. Comparison is made on the basis of whether the TMSs is using V2V or V2I infrastructure, mitigating traffic congestion or providing flow control and type of services offered.

In “PaaS “the vehicular clouds provides a platform for other related services like content downloading and sharing. This also provides platform for traffic management authorities to have access to all of the vehicles on the road. Other service like “StaaS” VCC enable us to have access to huge storage capacity which is distributed over large number of vehicles. For “CaaS” the VCC utilize processing power of vehicles and distribute data processing among number of vehicles participating in the cloud.

As explained in cloud taxonomy section multiple clouds cooperate with each other in order to share services among them. For example a V2V cloud collaborate with Internet cloud in order to have access to internet based remote server (traffic information system). These services are analyzed and a comparison is provided in Table 2. It is clear from the Table 2 that the trend is towards more internet cloud independency and not all the TMSs are really mitigating traffic congestion but just claiming.

Table 2. Comparison of VCC based TMS's proposals and prototypes

TMS article	V2I	V2V	Traffic flow control	PaaS	STaaS	CaaS	CSaaS
[29]	yes	yes	yes	yes	yes	yes	yes
[30]	yes	yes	yes	yes	yes	yes	no
[31]	yes		no	yes	yes	yes	no
[32]	yes		yes	yes	yes	yes	no
[33]	yes	yes	yes	yes	no	yes	yes
[34]	yes	yes	no	yes	no	yes	yes
[35]	yes	yes	yes	yes	yes	yes	no
[36]	yes	yes	yes	yes	yes	no	no
[37]	yes	yes	yes	yes	no	yes	yes
[38]	yes	yes	yes	yes	yes	yes	yes

TMSs are mostly relying on V2I infrastructure then V2V and on both infrastructures as well. All of the TMSs are claiming and providing PaaS and STaaS is not providing by all. The emerging services like cloud cooperative sensing as a service (CSaaS) are not common in recent known VCC based TMSs. Few of them is providing CSaaS only which is in the form of participatory type of sensing and it is not fully cooperative.

4 Traffic Management Challenges and Solutions

Few of the main challenges are discussed in following paragraphs. These challenges are not yet handled properly.

Resource Management: One of the important solutions to overcome these problems is to allocate the accurate amount of resources at right time as compared to the pre-allocation of resources. There is a need of the real time traffic related information. The VCC can help in finding the appropriate solution by using the available resource of vehicle without waiting for officials and DMCs.

Infrastructural Support in Evacuation: The VCC can provide infrastructural support during disaster and emergency situations. The disaster management authority can utilize VCC for evacuation. VCC provides the efficient information related to time, place and the availability of necessary resources such as food, water, shelter etc. The vehicles participating in the evacuation procedure forms vehicular cloud and coordinates with the rescue response teams.

Road Safety and Warning: If there is an incident/event occurs on the road then the vehicle inform/warn nearby vehicle and so on to the vehicular cloud regarding speed, location and direction of the incident/event. This early information or warning is very helpful for the vehicles so that they may decide/re-rout for the rest of the journey.

Intersection Congestion Management: Most of the time vehicles must have to, pass through the intersections. Because where there is a congested and highly populated area, there is a greater possibility of shopping malls, hospitals, schools and other frequently visiting buildings. The VCC can play a role in intersection management. The latest updated information on the vehicular cloud can provide an efficient solution to the drivers. This early information or warning is very helpful for the vehicles so that they may decide/re-route for the rest of the journey.

Communication Challenges: The communication among vehicles, vehicles to RSUs and vehicle to cloud (e.g. internet cloud) is critical. The vehicle's decisions related to safety and comfort depends on successful communication. The probability of successful communication depends on various factors like spectrum congestion, cost of internet use and on type of technology being used for communication.

Incorporation of IoVs: The impact of new technological advancements in the field of VANET, cloud computing and IoVs has not yet been fully realized. There is much need of the integration of such technologies to cope the challenges of the traffic congestion and transportation. Furthermore, how to balance the computations among local vehicles, vehicular clouds and Internet cloud so as to achieve different goals by IoVs. Future is of internet of things (IoTs) and big data, therefore the vehicular cloud cooperation is an intermediator in this paradigms shift. The devices and services collaboration among multiple clouds can be done by fully realizing the IoVs.

5 Conclusion

The VCC have great potential to change our lives on the road, by utilizing and sharing resources of vehicles with other vehicles to manage the traffic during congestion. The VCC provides an efficient enhancement to the message dissemination, traffic management and congestion control. The comparative analysis of VANET and VCC based TMSs is provided to show the purpose oriented scope of vehicular clouds and their use in road traffic management. The future challenges and their solution in terms of vehicular cloud cooperation is predicted. The VCC is envision to play an important role in further development of intelligence transportation system. The VCC and its emerging form of IoVs has great potential to derive the autonomous vehicles more efficiently.

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