# Vehicular Cloud Computing: Trends and Challenges

Kayhan Zrar Ghafoor*, Kamalrulnizam Abu Bakar†, Marwan Aziz Mohammed*, Jaime Lloret‡
*Faculty of Engineering, Koya University, Daniel Miterrand Boulevard, Koya, KOY45, Kurdistan
†Faculty of Computer Science and Information Systems, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor D. T, Malaysia
‡Departamento de Comunicaciones, Universidad Politecnica de Valencia, Camino de Vera s/n 46022, Valencia, Spain

***Abstract*—Recently vehicular Ad hoc Networks (VANET) has attracted the attention of research communities, leading car manufactures and governments due to its potential applications and specific characteristics. Their research outcome was started with awareness between vehicles for collision avoidance to internet access and then expanded to vehicular multimedia communications. Moreover, vehicle's high computation, communication and storage resources are set a ground for vehicular networks to deploy these applications in the near future. Nevertheless, on-board resources in vehicles are mostly underutilized. Vehicular Cloud Computing (VCC) is developed to utilize the VANET resources efficiently and hence provide subscribers safe and infotainment services. In this article, we perform a survey of state-of-the-art vehicular cloud computing as well as the existing techniques that utilizes cloud computing for performance improvements in VANET. We then classified the VCC based on the applications, services types and vehicular cloud organization. We present the detail for each VCC application and formation. Lastly, we discussed the open issues and research directions related to VANET cloud computing.**

***Keywords*—VANET, mobile cloud computing, VANET cloud, traffic information management.**

## I. Introduction

Recently, the growth in the number of vehicles on the road has put great stress on transportation systems. This abrupt growth of vehicles has made driving unsafe and hazardous. Thus, existing transportation infrastructure requires improvements in traffic safety and efficiency. To accomplish this, Intelligent Transportation Systems (ITS) have been considered to enable such diverse traffic applications as traffic safety, cooperative traffic monitoring and control of traffic flow. These traffic applications would become realities through the emergence of VANET because it is considered as a network environment of ITS. The increasing necessity of this network is an impetus for vehicle manufacturers, research communities and government agencies to increase their efforts toward creating a standardized platform for vehicular communications (for instance, Vehicle Safety Communication Consortium, Network-on-Wheels and Honda's Advances Safety Vehicle Program [1]). In particular, the 5.9 GHz spectrum band has been allocated for licensed Short Range Communication (DSRC) between vehicles. In addition, in the near future, more vehicles will be embedded with devices that facilitate communication between vehicles, such as Wireless Access in Vehicular Environment (WAVE) [2]. When vehicles are equipped with WAVE, they can communicate with nearby cars and access points within their coverage area.

In addition, car manufactures have advanced and hence fitted out better storage, computation and communication devices in the vehicles. These advances are all for the sake of improving traffic safety and efficiency [3], [4], [5], [6]. A long with this development, vehicles can also access internet services and thereby various benefits will be offered to the drivers and passengers [7]. Thus, these advancements in vehicular technology and communication will provide wide potential applications to meet safety and comfort requirements for driver. However, the phenomenal on-board resources is remaining under-utilized by the aforementioned applications [8].

In an attempt to address the problem of resource underutilizing, the authors in [9] have proposed the concept of vehicular cloud. VCC is defined as paradigm shift from conventional VANET to vehicular cloud in which vehicles use their on-board resources and cloud resources as well [10], [11]. The motivation of merging mobile cloud computing with VCC are the dynamic accessibility of resources. In other words, the VCC follows the concept of pay as you go model instead of buying resources and infrastructure. With this technology, vehicle's communication, computing and storage capabilities can be combined with those of other drivers or rented to the participated cars. This concept is similar to the traditional cloud computing but sensing nodes in VANET are vehicles and they travelling with high speed. VCC is still in it's infancy stage of researching and need to be explored more [12]. Figure 1 shows the number of articles published in the last years.

In this paper, we surveyed the state-of-arts of vehicular clouds, which is considered as a development of traditional cloud computing with novel features. More precisely, the

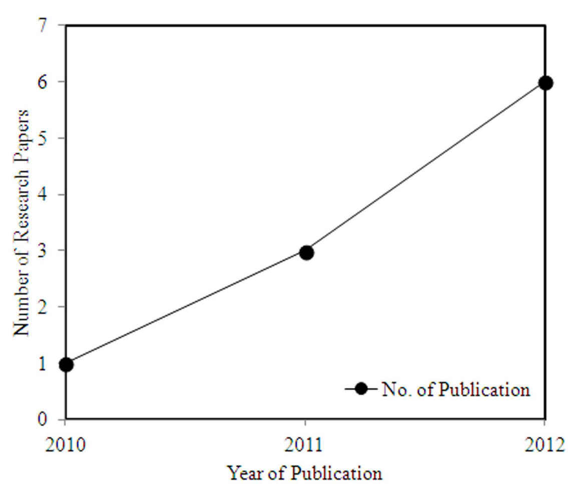


Figure 1. Number of publications in the last years

aim of this paper are to introduce the concepts of vehicular clouds and highlight the prospective applications for sake of improving the efficiency of vehicular networks. We explained the existing techniques that utilizes cloud computing for performance improvements in VANET. We then classified the VCC based on the applications, services types and vehicular cloud organization. Moreover, we explained the communication paradigm and organization of vehicular clouds. Based on this though study on VCC, we discussed the open issues and research directions related to VANET cloud computing. To the best of our knowledge, this research paper is the first attempt in thoroughly reviewing state-of-arts of VCC and highlighting its challenges.

The rest of the paper is organized as follows: Section 2 provides an overview of the current state of the arts of VANET. The cloud computing taxonomy and its illustration are discussed in section 3, followed by the discussion on vehicular cloud computing and its architecture, where we also highlight the applications of vehicular clouds and the layers of the vehicular clouds. Finally, section 4 concludes the paper and discusses future directions.

## II. VANET

The number of vehicles contending for space in existing transportation systems is growing rapidly. This abrupt growth of vehicles has made driving unsafe and hazardous. Thus, existing transportation infrastructure requires improvements in traffic safety and efficiency. To achieve this requirement, Intelligent Transportation Systems (ITS) have been considered to enable diverse traffic applications such as traffic safety, cooperative traffic monitoring and control of traffic flow. Vehicular networks are considered as a network environment for ITS.

Over the past decade, the employing of vehicular communications to support traffic safety and comfort related services have earned much attention in both industry and academia. A divergent number of wireless technologies have been used such as Infrared (infrared) [13], Bluetooth [14] and cellular [15]. However, IEEE 802.11 based solutions has witnessed to be the popular and appropriate solution. This advancement are continued as the IEEE 802.11p [16], [17] amendment to the standard is attracting increasing interest. A range of flourish applications are required to aim the uptake of vehicular communications and massive number of solutions have already been proposed, with safety applications being the most prominent [18], [19]. These traffic safety applications are relying on Inter-vehicle Communications (IVC) and the formation of VANET. In addition to the traffic safety services, VANET offers prosperous services like internet on the wheel, high-speed tolling, information infotainment and video on demand [20], [21]. Due to high mobility of vehicles, however, many research challenges still need to be addressed.

## III. Cloud Computing

Cloud computing is a style of a new computing paradigm that enables on-demand service to consumers through various cloud service providers. These cloud computing services can be accessed through internet from configured and shared resources like computing storage and applications in a virtual manner. Some of the services are provided for free while others are based on 'pay as you go' model from hardware and system software in remote datacenters [22], [23], [24]. The cloud service providers manage a network infrastructure of datacenters in order to combine the computing power of massive number of servers. Moreover, the 'pay as you go' characteristics of cloud computing enable many advantages such as non-front investment, lower operating cost, highly scalable and easy access. Example of cloud computing are Amazon S3, Google Drive and Microsoft SkyDrive and they could provide virtualized infinite amount of resources.

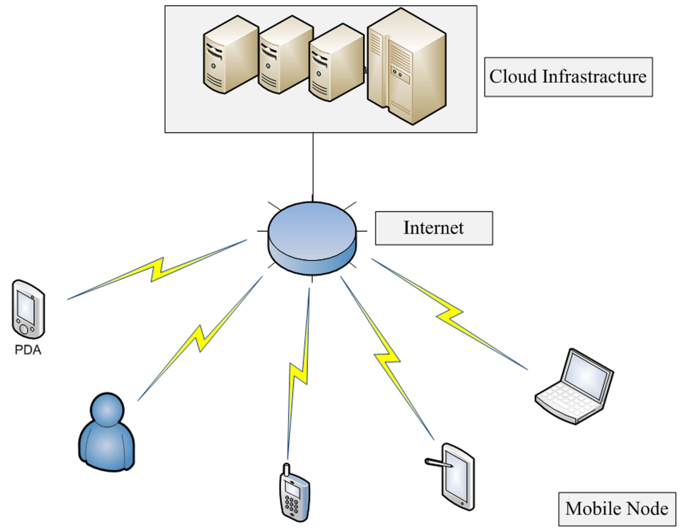

Figure 2. Mobile cloud computing communication paradigm

With the existence of a pool of resources in mobile environment, a new computing field is emerged called Mobile Cloud Computing (MCC) [25]. In this environment, every mobile device can act as mobile client or service provider. It is witnessed that the popularity of mobile devices (e.g., tablet computer, i Pad, and smartphone) for internet access are increasing day-by-day as compared to stationary personal computers. This is because significant improvements of mobile devices have shown in terms of hardware, operating system and transmission capability. Recently many mobile application like real time services, instant email checking, social networking can be performed ubiquity through mobile device. These mobile devices effectively form mobile cloud to access internet cloud ubiquity. For instance, a mobile device interested in downloading an application from nearby mobile node. This information is stored and propagated in the mobile cloud [26]. Moreover, there are many services of MCC such as Googles gmail, Maps and Navigation systems for mobile, Voice Search, and some applications on an Android platform, that offers great applications to the end users. The general architecture of MCC is illustrated in Figure 2 below [25].

### A. Vehicular Cloud Computing

A massive number of resource-rich vehicles that are travelling on the highways and urban areas posses internet access services, on-board storage, high computation and sensing capabilities. In our daily life, many vehicles spend a substantial time in malls, parking garages and drive ways. With these features, vehicles can be utilized as a cloud node within neighbourhood cars that are involved in the cloud formation. Indeed, the drivers may rent their vehicle's on-board resources to the cars that are demanding specific service for stipulated time period [9]. In such situations, vehicles have the capability to cooperate for the sake of solving problems that would happen in centralized system. For instance, a driver raise the question to vehicular cloud regarding the cause of traffic jam in the next road segment. In response to this query, the vehicular cloud create, maintain and propagate this information to the relevant vehicles. Internet cloud also can be used to query this type of information but at the expensed of inordinate amount of time for querying and searching information in the global cloud. Thus, vehicular cloud computing has many advantages as compared to the conventional cloud computing [26], [27].

More significantly, vehicular clouds have various crucial applications ranging from traffic safety, environment sensing, information distribution to the commercial advertisement and traffic infotainment. For instance, vehicles will capture information like traffic condition, road condition, cars in the vicinity, environment condition and surveillance videos via equipped sensors. This group of vehicles in a specific road segment can exchange and maintain this information rather than uploading to the internet cloud. Among group of vehicles, participated cars can excess the cloud data in the VC.

Recently, car manufacturing companies and governments of several countries attempt to promote the cloud computing in the vehicular networking. For example, in the USA, the Federal Communications Commissions allocated Dedicated Short Range Communications (DSRC) with a range of 75 MHz of the spectrum (5.850 to 5.925 GHz) in support of vehicular networking [3], [28], [29]. Moreover, roadside infrastructures such as inductive loop detectors, video cameras, acoustic tracking systems, microwave radar sensors, and access points are also helpful for VCC. As part of a project, Ford motor company combines social networks, GPS location awareness, and real-time vehicle data in ways that help drivers go where they want efficiently by using the cloud(2012). Ford is equipped with cloud features called Ford SYNC, which connects customers to real time traffic updates, information, turn-by-turn driving directions, business, sports, weather, and news through voice commands. Recently, Toyota and Microsoft announced a new, 12 million partnership to bring cloud computing to Toyota vehicles [30]. The partnership will equip Toyota vehicles with the latest technology to access telecommunications information, streaming music, energy management, and GPS services, while on the road. We also consider another motor company named General Motors. The General Motor perception and vehicular control groups are engaged in developing a vehicle to vehicle communication system. This system relies on DSRC with a range of about one-quarter mile (400 m) in all directions, with radios connected to traffic lights or construction zones. The technology will provide viable solutions for essential safety information for drivers. Figure 3 presents a taxonomy of vehicular cloud computing.

*1) Architecture of Vehicular Clouds:* The vehicular cloud computing composed of three layers of communication. As can be seen in Figure 4, the three communication layers are on-board layer, communication layer and cloud computing layer. In the on-board layer, a vehicle could sense the environment

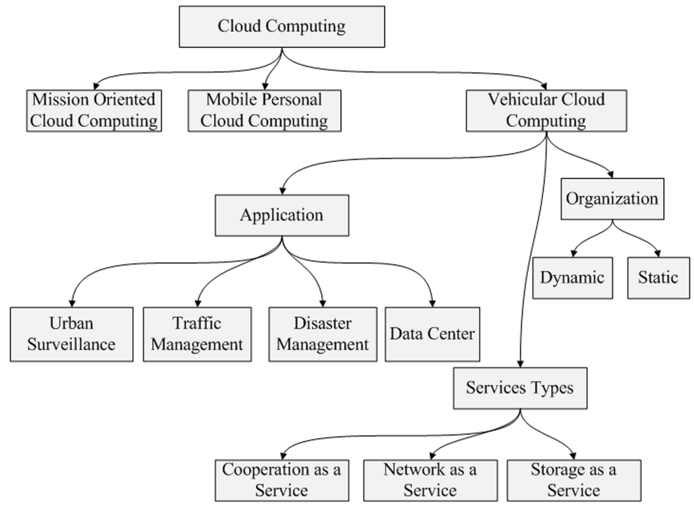


Figure 3. Taxonomy of the literature on vehicular cloud computing

condition, road condition or other parameters and these collected data will be shared with neighbourhood vehicles in the vicinity. Perhaps beacon frame is used to synchronize and handshake among vehicles and hence sharing operational data. The second layer enables communication between vehicles and vehicular clouds. As vehicles are equipped with IEEE 802.11p transceivers, they can exchange information either vehicle-to-vehicle (V2V) or vehicle-to-infrastructure (V2I) by using Wi-Fi, IEEE 802.11p, WiMAX or 3G cellular communications.

In V2V architecture, cars communicate with each other in the vicinity in order to enable traffic safety for the drivers and passengers as well as comfort related applications. As it was witnessed in the past decade, this communication has important role in reducing number of crashes, collisions in vehicular scenarios. VCC also can be formed among V2V communication scenarios, in case of abnormal road condition or driver behaviour, a vehicle that observed this traffic abnormality will send an event-driven emergency message to the formed vehicular cloud storage and hence all vehicles that are registered within this VC will receive the emergency message. Event-driven emergency message contains the positional information of the location where abnormal situation occurs [31], [32], [19], [33]. Moreover, VANET utilizes fixed gateways such as WLAN access points, WiMAX base stations or 3G networks in order to exchange packets among vehicles and internet. The V2I is complementary to V2V architecture and can raise driver safety and reduce traffic deaths and injuries by implementing collision avoidance and warning systems [34]. As V2I requires high cost of infrastructure installation, V2V is considered more feasible [35]. It is worth mentioning that traditional vehicular networks consists of the lower two layers: on-board and communication layers. Moreover, the cloud computing layer provides communication at the cloud level through roadside unit or mobile gateways.

The cloud computing layer of vehicular cloud consists of three sub-layers i.e cloud as an infrastructure, cloud as a platform and cloud as service. Cloud as an infrastructure provides Computation and storage capabilities for vehicles. The sensed data is classified based upon the type of information and then stored in the storage unit of a vehicle. Then, vehicles use their

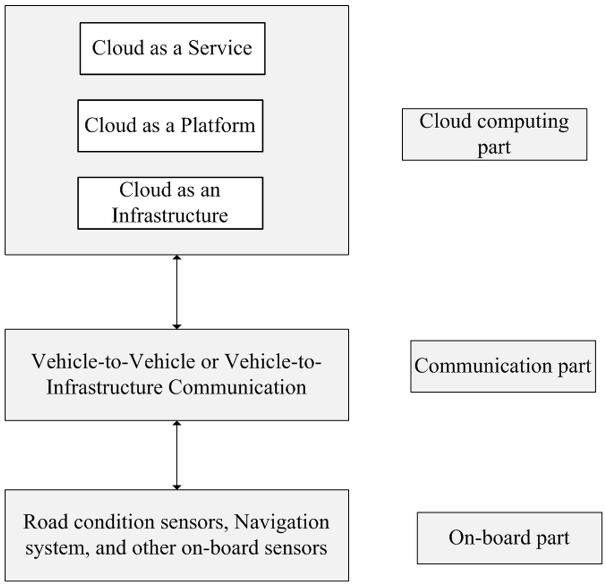


Figure 4. Vehicular cloud computing architecture

computation capability to analyse the data that is stored in the storage unit. Cloud as a platform consists of development tools that are hosted in the cloud and accessed via a group of vehicles within the same cloud. Moreover, the cloud as a service offers network as service, cooperation as a service and storage as a service [9]. Some vehicles have internet access while they are moving. Those vehicles can share this luxury with neighbour vehicles within the same vehicular cloud. In the same way, some vehicles have sufficient amount of storage while others need extra storage. storage as a service can offer storage to the vehicles which need extra storage. Cooperation as a service also is used to provide various services to the drivers via V2V communication.

*2) Organization of Vehicular Cloud Computing:* The vehicular cloud is formed as follow

1. Static VC

In our daily life we spend a substantial amount of time on the street and parking lot. On the roads, the traffic situation is dynamic and is varied from normal to abnormal scenarios such as traffic congestion and accidents. In such abnormal traffic conditions, VC is mimic to the traditional cloud computing services. This similarity between VC and traditional cloud computing is also true when vehicles remain static in malls or parking garages. Consider an information technology company that offers IT services and solutions to its customers. In such company many vehicles of staff members remain idle in the parking lot and their computational resources also remain unutilized. The companies top management may request the formation of static vehicular cloud by providing rewards to those employees who want to rent the on-board resources of their vehicles. As a result, the formed static VC will take benefit from the cooperation of on-board resources of vehicles that are participating in the cloud formation. Figure 5 shows the static formation of vehicular cloud. As can be seen in Figure 5, vehicles are parked in front of the company and this company offers incentive to the drivers who will rent on-board resources of their vehicles. This kind of VC formation is called stationery

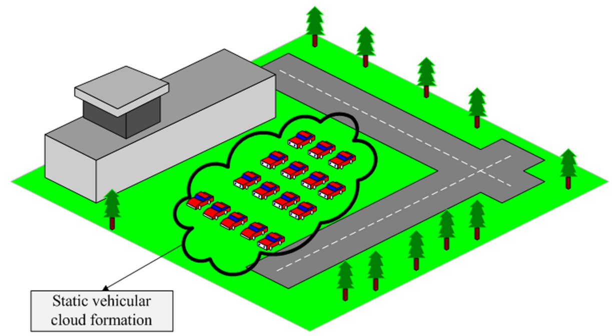


Figure 5. Static Vehicular cloud formation

VC since all vehicles are static.

2. Dynamic VC

Advances in vehicular networks in one hand and cloud computing in the other motivates the necessity of dynamic formation of VC. As vehicles are travelling with high mobility and the network changes rapidly, the mobility parameter play an important role in VC formation. Mobile vehicular cloud would be formed among vehicles with similar mobility. The reason is that among similar velocity vehicles the relative velocity will be reduced and the cloud will long lasted. Thus, moving vehicles can make a cloud of storage and computation resources autonomously. The process of dynamic VC formation is mimic to the dynamic cluster formation in VANET.

Dynamic VC is formed by first electing a vehicle that has smallest value of relative mobility to the nearby cars. The elected vehicle is known as cloud head and will form the VC by inviting the neighbour vehicles to join its VC. The invited neighbour vehicles should response back the request from the cloud head. If the number of vehicles are sufficient, the cloud head will declares the cloud formation. Thus, VC enables a seamless integration and pooling of resources of the vehicles that are registered in the VC. With this capability, the VC provides a large computer cluster and a huge distributed data storage facility [10]. In contrast to stationary formation of VC, Figure 6 illustrates that the neighbour vehicles are involved in formation of dynamic vehicular cloud. This is called dynamic VC since all vehicles within the VC are travelling on the roads.

*3) Applications of Vehicular Cloud Computing:* In this section several possible implementation scenarios and the application outcome of VCC are discussed [10], [11], [26], [36]:

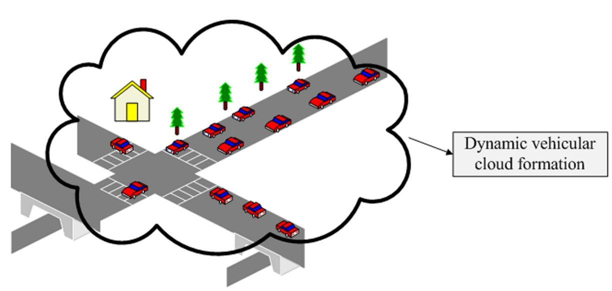


Figure 6. Dynamic Vehicular cloud formation

Figure 7. Urban surveillance system in VC

1. Datacenter Formation

In our daily life, people are spending hours in malls for shopping purpose in holidays or weekends. As illustrated in Figure 7, many cars are parked in the parking garage and their owners spend substantial amount of time for shopping. During the time of shopping, these cars remain idle with under-utilized computation resources. These on-borad resources can shared/rented to the interested customers with permission of the cars owners. This process can be handled by the mall IT management department. For instance, each vehicle has Ethernet interface and in each parking spot the mall management should provide Ethernet cable. If a driver intends to rent the resources of its car, he need to connect the Ethernet cable to vehicle's Ethernet interface. In this case, The mall management should reward drivers who rented the on-board resources of their vehicles for the sake of static VC formation.

Some people are travelling from a country to the other one. When they travel, they left their vehicles in the parking lot of an airport. It is a great opportunity to exploit the resources of these vehicles in order to form a VC in a parking spot. For instance, the airport management section can offer power source, storage or Ethernet connection to the vehicles that are interested to rent those resources for a stipulated time period. The participated vehicles in a VC will reveal their arrival and departure times. This information helps the airport management to schedule the shared on-board resources. Thus, long-term parking lot and sharing travel plan by participated cars will provide plentiful, stable and long-term resources [10].

2. Disaster Management

The reaction to emergency situations is very important as it's consequences are very catastrophic. For instance, the Japan earthquake, 11 September in USA and other disasters. The total cost of Japan tsunami is approximately about 300 billion USD [36]. Certainly, communication technology has crucial role in responding emergency situations and hence reducing human death toll. VCC can be used to manage disaster events by forming vehicular clouds that are participating in the evacuation operation. The evacuation system should provide an safe area for the people when a disaster situation occurs in a city . For instance, evacuation zones should be chosen based on the low travelling time and availability of resources

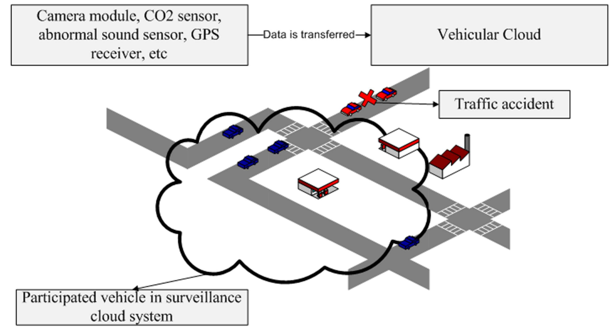


Figure 8. Urban surveillance system in VC

such as medicine, food and water. The authors in [36] proposed intelligent disaster management system for Ramadi city in Iraq. The proposed work leverage vehicular networks and MCC for the evacuation procedure in case of unpredicted disaster.

3. Traffic Management

Nowadays the on-board navigator can estimate the traffic fluidity and patterns from MC and forwards the optimal route to the vehicles. The navigator service enables traffic management through the communication between on-board and server navigator. The on-board navigators send time, position and position of destination in a fixed rate to a server navigator in internet. The server responses back the best route based on the estimated load and delay on the incremental route to the destination. This cooperation is considered as an interaction between VC and internet cloud. More precisely, the VC through on-board navigator senses the traffic congestion of road segments whereas the internet cloud through server navigator estimates the traffic flow on those roads. With the help of such applications, vehicles can compute local traffic of roads and determine the reasons of traffic jam in order to address the traffic deadlock and react accordingly [26].

4. Urban Surveillance

Vehicles in VANET are equipped with sensors and they communicate with each other for mobile surveillance and environment monitoring. Traditional urban surveillance systems for monitoring security attacks rely on the fixed roadside infrastructure. This method is not efficient as compared to the mobile surveillance via vehicles. With cooperation of VCC video surveillance can be done on-demand via vehicles that are travelling on the urban roads and highways. For urban surveillance, self-organized vehicles participating in surveillance system will form a vehicular cloud and they can report any suspected activity such as terrorist attack to a specific zone. Mobile surveillance can also be used in investigations after the event has occurred. For instance, after any event the video file exist in the storage of a vehicle and it can be used in forensic investigation (investigation of a platoon of crashes in the urban area) [26]. Figure 8 shows an example of urban surveillance system integrated with VC. As can be seen, the blue vehicles are considered as self-organized cars and they formed vehicular cloud for surveillance activities. For instance, the on-board video surveillance that is stored in the VC can be used to investigation on the traffic accident between red vehicles.

## IV. CONCLUSION

Vehicles have powerful source of computing and sensing on-board resources that are useful for traffic safety and comfort-related applications. These underutilized resources can be pooled among all vehicles in the vicinity. Vehicular clouds has emerged due to high vehicle's computation and storage resources, sensing capabilities and traditional cloud computing. The VCC is considered as a complementary of traditional cloud computing but with more services and applications. Participated vehicles can share/rent their on-board resources such as computation, storage and internet access, to the VC subscribers. When the VC is fully deployed, many applications would be realized such as urban surveillance, environment monitoring, reducing traffic accidents, traffic and disaster managements. The outcome of these applications will impact the drivers and the community.

In this paper, We presented the classification of VCC based on the applications, services types and vehicular cloud organization. We then highlighted the communication paradigm of VCC that consists of three layers: car level, communication layer and cloud layer. We also pointed out the crucial applications of VCC such as urban surveillance and monitoring, traffic and disaster management, and datacenter formation in VC.

VCC is new and exciting topic and still need to be explored by the research community and academia. The research opportunities and directions are falls in the various areas of study such as security issues in formation of VC and sharing information in VC, geographical routing in VC, and algorithms for disaster management using VC.

## REFERENCES


[1] S. Olariu, M. C. Weigle, Vehicular Networks from Theory to Practice. 1st. ed., Chapman and Hall Pub., 2009.

[2] ITS-Standards, Intelligent transportation systems, U.S. Department of Transportation, http://www.standards.its.dot.gov/about.asp (1996).

[3] K. Ghafoor, K. Bakar, E. van Eenennaam, R. Khokhar, A. Gonzalez, A fuzzy logic approach to beaconing for vehicular ad hoc networks, Telecommunication Systems Journal Online pre-publication. ISSN 1018-4864. June 2011.

[4] C. Sommer, O. Tonguz, F. Dressler, Adaptive beaconing for delay-sensitive and congestion-aware traffic information systems, in: Proceedings of the 2010 IEEE International Vehicular Networking Conference (VNC), Jersey: IEEE, 2010, pp. 1 – 8.

[5] V. Naumov, R. Baumann, T. Gross, An evaluation of inter-vehicle ad hoc networks based on realistic vehicular traces, in: Proceedings of the 7th ACM International Symposium on Mobile Ad Hoc Networking and Computing, Florence, Italy: ACM, 2006, pp. 108 – 119.

[6] K. Z. Ghafoor, K. Abu Bakar, J. Lloret, R. H. Khokhar, K. C. Lee, Intelligent beaconless geographical forwarding for urban vehicular environments, Wireless Networks 19 (3) (2013) 345–362. Springer–Verlag New York, Inc.

[7] R. Hussain, J. Son, H. Eun, S. Kim, H. Oh, Rethinking vehicular communications: Merging vanet with cloud computing, in: Proceedings of the 2012 IEEE 4th International Conference on Cloud Computing Technology and Science (CloudCom), New Orleans, LA: IEEE, 2012, pp. 606–609.

[8] F. Li, Y. Wang, Routing in vehicular ad hoc networks: A survey, IEEE Vehicular Technology Magazine 2 (2) (2007) 12 – 22. IEEE.

[9] M. Eltoweissy, S. Olariu, M. Younis, Towards autonomous vehicular clouds, Ad Hoc Networks 2 (2) (2010) 1–16. Elsevier.

[10] S. Olariu, I. Khalil, M. Abuelela, Taking vanet to the clouds, International Journal of Pervasive Computing and Communications 7 (1) (2011) 7–21. Emerald Group Publishing Limited.

[11] H. Abid, L. T. T. Phuong, J. Wang, S. Lee, S. Qaisar, V-cloud: vehicular cyber-physical systems and cloud computing, in: Proceedings of the 2011 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies, San Francisco: ACM, 2011, pp. 165–170.

[12] S. Arif, S. Olariu, J. Wang, G. Yan, W. Yang, I. Khalil, Datacenter at the airport: Reasoning about time-dependent parking lot occupancy, IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS 23 (11) (2012) 2067–2080. IEEE.

[13] J. S. Kwak, J. H. Lee, Infrared transmission for intervehicle ranging and vehicle-to-roadside communication systems using spread-spectrum technique, Intelligent Transportation Systems, IEEE Transactions on 5 (1) (2004) 12–19.

[14] A. Sugiura, C. Dermawan, In traffic jam ivc-rvc system for its using bluetooth, Intelligent Transportation Systems, IEEE Transactions on 6 (3) (2005) 302–313.

[15] J. Santa, A. F. Gómez-Skarmeta, M. Sánchez-Artigas, Architecture and evaluation of a unified v2v and v2i communication system based on cellular networks, Computer Communications 31 (12) (2008) 2850–2861.

[16] D. Jiang, L. Delgrossi, Ieee 802.11 p: Towards an international standard for wireless access in vehicular environments, in: Proceedings of the 2008 Vehicular Technology Conference, IEEE, 2008, pp. 2036–2040.

[17] R. Uzcategui, G. Acosta-Marum, Wave: A tutorial, IEEE on Communications Magazine 47 (5) (2009) 126–133. IEEE.

[18] L. Yang, J. Guo, Y. Wu, Piggyback cooperative repetition for reliable broadcasting of safety messages in vanets, in: Proceeding of the 2009 Consumer Communications and Networking Conference, Anchorage, AK: IEEE, 2009, pp. 1–5.

[19] L. Yang, J. Guo, Y. Wu, Congestion control for safety messages in vanets: Concepts and framework, in: Proceeding of the 8th International Conference on ITS Telecommunications, ITST 2008, USA: IEEE, 2008, pp. 199–203.

[20] J. Anda, J. LeBrun, D. Ghosal, C.-N. Chuah, M. Zhang, Vgrid: vehicular adhoc networking and computing grid for intelligent traffic control, in: Proceedings of the 61st IEEE Vehicular Technology Conference, 2005, Spain: IEEE, 2005, pp. 2905–2909.

[21] G. Karagiannis, O. Altintas, E. Ekici, G. Heijenk, B. Jarupan, K. Lin, T. Weil, Vehicular networking: A survey and tutorial on requirements, architectures, challenges, standards and solutions, IEEE Communications Surveys & Tutorials 13 (4) (2011) 584–616. IEEE.

[22] J. J. Rodrigues, L. Zhou, L. D. Mendes, K. Lin, J. Lloret, Distributed media-aware flow scheduling in cloud computing environment, Computer Communications 35 (15) (2012) 1819–1827. Elsevier.

[23] T. W. Wlodarczyk, C. Rong, An initial survey on integration and application of cloud computing to high performance computing, in: Proceedings of the 2011 IEEE Third International Conference on Cloud Computing Technology and Science, USA: IEEE, 2011, pp. 612–617.

[24] W. Song, X. Su, Review of mobile cloud computing, in: Proceedings of the 2011 IEEE 3rd International Conference on Communication Software and Networks, Turkey: IEEE, 2011, pp. 1–4.

[25] P. Gupta, S. Gupta, Mobile cloud computing: The future of cloud, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering 1 (3) (2012) 134 – 145. ISO.

[26] M. Gerla, Vehicular cloud computing, in: Proceedings of the 2012 The 11th Annual Mediterranean on Ad Hoc Networking Workshop, Philadelphia, PA: IEEE, 2012, pp. 152–155.

[27] Y.-W. Lin, J.-M. Shen, H.-J. Weng, Cloud-assisted gateway discovery for vehicular ad hoc networks, in: Proceedings of the 2011 5th International Conference on New Trends in Information Science and Service Science, USA: IEEE, 2011, pp. 237–240.

[28] K. Ghafoor, K. Bakar, S. Salleh, K. Lee, M. Mohamad, M. Kamat, M. Arshad, Fuzzy logic-assisted geographical routing over vehicular ad hoc networks, International Journal of Innovative Computing, Information and Control 8 (6) (2012) 1 – 26. TOKAI University.

[29] K. Ghafoor, K. Bakar, Inter-vehicle communication protocols for multimedia transmission, in: Proceedings of the 2010 IAENG International MultiConference of Engineers and Computer Scientists, Hong Kong: IAENG, 2010, pp. 1234–1239.

[30] R. Liu, Microsoft and toyota bringing the cloud to cars, in: SLASH and GEAR, Istanbul: IEEE, 2011.

[31] C. Chen, J. Lee, C. Wu, Y. Kuo, Fairness and qos guarantees of wimax ofdma scheduling with fuzzy controls, EURASIP Journal on Wireless Communications and Networking 2009 (2009) 1 – 14. Hindawi Publishing Corp.

[32] L. Yang, J. Guo, Y. Wu, Channel adaptive one hop broadcasting for vanets, in: Proceedings of the 2008 IEEE International Conference on Intelligent Transportation Systems, Beijing : IEEE, 2008, pp. 369–374.

[33] Q. Xu, T. Mak, J. Ko, R. Sengupta, Vehicle-to-vehicle safety messaging in dsrc, in: Proceedings of the 2004 ACM International Workshop on Vehicular Ad hoc Networks, Philadelphia, PA: ACM, 2004, pp. 28–38.

[34] L. Bordley, C. R. Cherry, D. Stephens, R. Zimmer, J. Petrolino, Commercial motor vehicle wireless roadside inspection pilot test, part b: Stakeholder perceptions, in: Proceedings of the 91st Annual Meeting on Transportation Research Board, USA: IEEE, 2012, pp. 6–12.

[35] C. Huang, Y. Fallah, R. Sengupta, H. Krishnan, Adaptive intervehicle communication control for cooperative safety systems, IEEE Network 24 (1) (2010) 6 – 13. IEEE.

[36] Z. Alazawi, S. Altowaijri, R. Mehmood, M. B. Abdljabar, Intelligent disaster management system based on cloud-enabled vehicular networks, in: Proceedings of the 2011 11th International Conference on ITS Telecommunications, UK: ITST, 2011, pp. 361–368.