Cloud Computing in VANETs: Architecture, Taxonomy, and Challenges

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ABSTRACT

Cloud Computing in VANETs (CC-V) has been investigated into two major themes of research including Vehicular Cloud Computing (VCC) and Vehicle using Cloud (VuC). VCC is the realization of autonomous cloud among vehicles to share their abundant resources. VuC is the efficient usage of conventional cloud by on-road vehicles via a reliable Internet connection. Recently, number of advancements have been made to address the issues and challenges in VCC and VuC. This paper qualitatively reviews CC-V with the emphasis on layered architecture, network component, taxonomy, and future challenges. Specifically, a four-layered architecture for CC-V is proposed including perception, co-ordination, artificial intelligence and smart application layers. Three network component of CC-V namely, vehicle, connection and computation are explored with their cooperative roles. A taxonomy for CC-V is presented considering major themes of research in the area including design of architecture, data dissemination, security, and applications. Related literature on each theme are critically investigated with comparative assessment of recent advances. Finally, some open research challenges are identified as future issues. The challenges are the outcome of the critical and qualitative assessment of literature on CC-V.

1. INTRODUCTION

Recently, cloud computing has witnessed significant attention in vehicular communication. It is because of the realization of smart Intelligent Transport System (ITS) applications, and architectural similarity between Mobile Cloud Computing (MCC) and Vehicular Ad-hoc Networks (VANETs) [1-3]. Cloud Computing in VANETs (CC-V) has been investigated into two major dimensions of research in the area. Firstly, Vehicular Cloud Computing (VCC) has been explored. In VCC, group of connected vehicles forms a cloud with the aim of sharing their abundant resources.

VCC increases resource utilization in vehicular communication [4]. The abundant resources include storage, computing capability, sensing, and communication capability. The resources became available for sharing, when several vehicles assemble at the places including parking lots, garage, canteens, highway hold-up, and traffic lights. At these places, the idea of VCC has been realized. VCC dynamically allocates abundant resources to authorized users. Secondly, Vehicle using Cloud (VuC) has been explored in which the connected vehicles are considered. VuC enables the access to the services of conventional cloud at vehicles via Internet. VuC helps in realizing smart ITS applications including real time traffic prediction, and web-based services [5].

The investigations are in initial stages in both, VCC and VuC. There are opportunities and challenges considering a new area for cloud computing. In fact, huge resources of vehicles are underutilized at various places (where a group of vehicles assemble), which is needed to be explored and tap into [6]. The framework of CC-V improves the usability, reliability and efficiency of intelligent transportation system applications [7]. Subsequently, it enhances safety in transportation, reduces traffic congestion, decreases air pollution, and augments comfort in driving [8].

Some of the cloud computing services realized in CC-V include Network as a Services (NaaS), Storage as a Service (STaaS), Cooperation as a Service (CaaS), Computing as a Service (COaaS), and Sensing as a Service (SEaaS) [9-11]. Since, vehicles are considered to be able to connect to Internet, NaaS can be used by passengers to connect to the Internet in VuC. Applications and data of vehicles, which require more memory for storage can utilize STaaS of VCC [12]. CaaS can be utilized to share traffic information among vehicles in case of accident, and road maneuverer. Vehicles can realize smart ITS applications using COaaS to fulfill higher computation power requirement of smart-applications. SEaaS can be utilized for monitoring real time condition of car as well as driver's behavior [13]. Whaiduzzaman et al. [14] has explored VCC by presenting a taxonomy based on strategic management, security and privacy, cloud formations, inter-cloud communication and applications issues. An architecture for VCC, comparison with cloud computing and open research issues has been presented. However, the architecture has not been explicitly defined considering layer-wise function, representation, and protocol.

The network components related to VCC are also not explored.

Although various contributions have been made for realizing these cloud services in CC-V, yet there are number of issues that needs to be addressed in near future. In this paper, a qualitative review of cloud computing in VANETs has been presented. The review focuses on layered architecture, network component of CC-V, taxonomy of recent advances, and open challenges and issues for future direction of investigation in the area. A four layered architecture for CC-V is designed including perception, co-ordination, artificial intelligence and smart application layers. The representative components, responsibilities and protocols of each layer are described. The three network components of CC-V namely, vehicle, communication, and computation have been explored with their cooperative roles. From the best of our knowledge, there is no layered architecture available for CC-V. The major network components with their cooperative roles have not been explored previously. The taxonomy of CC-V is presented considering four major issues including design of architecture, data dissemination, security and application development. Each issue has been qualitatively, and critically reviewed with comparative assessments of recent advancements. Finally, some future challenges are identified according to the qualitative, and critical review of related literature.

The rest of this paper is organized as follows. Section 2 presents four layered architecture of CC-V. Section 3 describes three network components of CC-V. Section 4 presents a taxonomy of CC-V with qualitative and critical review of related literature. Some future challenges in CC-V are identified in Section 5, followed by conclusion made in Section 6.

2. LAYERED ARCHITECTURE

In this section, a four layered architecture for CC-V is designed in terms of representation, functionalities and protocol perspective. In a broader operational and structural point of view, CC-V has four major components namely, perception physical devices, co-ordination, artificial intelligence and smart application services. Therefore, the architecture consists of four layers including perception, co-ordination, artificial intelligence and smart-application (See Fig. 1). The perception layer is correlated with physical devices. The coordination layer is linked with communication networks. The artificial intelligence layer is associated with computation, and the smart application layer is correlated with the services. The layers effectively divides the functionalities of CC-V into four groups. The layers are unambiguously differentiable in terms of both functions and representations. Each layer is described below considering representative components and functionalities.

2.1 Perception Layer

The perception layer of the architecture represents in-vehicle devices including sensors, actuators, display unit, smart mobile devices, Global Positioning System (GPS) receiver, actuators etc. The two main functions of the layer include gathering traffic data through sensing, and delivering information at end level. The layer defines vehicle to physical world interactions through smart devices. Apart from the two functionalities, a number of services are provided by the perception layer to the

next layer as interface services. The interface services include error detection and correction on sensed data, result verification on inferred information, etc.

In terms of protocol perspective, physical layer part of the protocols including IEEE 802.11p (PHY-802.11p) of WAVE [15], 802.11a/b/g of WLAN [16], Wi-Max [17], 4G/LTE [18] are considered. This is due to the consideration of heterogeneous in-vehicle devices containing different types of sensors.

2.2 Co-ordination Layer

The co-ordination layer represents network devices and internetworking technologies. The network co-ordination is significant due to the consideration of different types of networks including VANETs, Wi-Fi and 4G/LTE. The main functionalities of the layer include transfer of data packet, and efficient handoff among these networks. The heterogeneous network architecture makes both the tasks quite challenging. The other functionalities of the layer include data dissemination in heterogeneous networks, location based networking support, network level authentication, and authorization.

In terms of protocol perspective, two sub-layers are considered. In the first sub-layer, MCA layer part of the protocols including IEEE 1609.4 [19] in WAVE, 802.11p, and LLC are considered. In the second sub-layer, network and transport protocols including Fast Application and Communication Enabler (FAST) [20-23] in CALM, Car-to-Car (C2C-net) [24] and Short Message Protocol (SMP) [19] in WAVE are considered apart from traditional IP and TCP/UDP combinations.
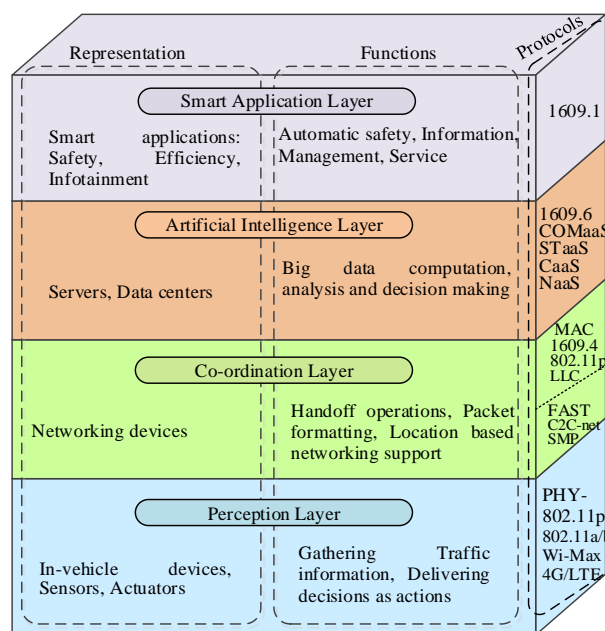

Figure 1. The Layered Architecture of CC-V

2.3 Artificial Intelligence Layer

The artificial intelligence layer represents cloud based computing infrastructure. It includes data centers, and servers of conventional cloud in case of VuC. The computing resources of vehicles are also included in case of VCC. The functionalities of the layer include big data computation, analysis and inferring intelligent decisions for real time applications. Apart from cloud computing and decision making, the other operations of

the layer include mining traffic data for new business models, ensuring computing efficiency, scheduling and paralleling computation, etc. The operations of the layer is very much similar to the operations of cloud based services. The layer significantly enhances the computing capability of vehicles through VuC architecture. It also improves the utilization of resources of vehicles through VCC architecture.

In terms of protocol perspective, the protocols related to service, Big Data Analysis (BDA) and Vehicular Cloud Computing (VCC) are considered. The protocols include IEEE 1609.6 of WAVE, Computing as a Service (COMaaS), Storage as a Service (STaaS), Picture as a Service (PICaaS), Infrastructure as a Service (INaaS), Cooperation as a Service (CaaS), Network as a Service (NaaS) and Gateway as a Service (GaaS). The design of protocols for BDA and VCC is an open research theme in CC-V due to the growing volume of traffic data.

2.4 Smart application Layer

The smart application layer represents smart cloud based applications of three categories including safety, efficiency and infotainment. The layer is responsible for delivering end user smart services. The layer operations include application management, service management, application and service based data management, application based authentication, and authorization. Although the applications for safety and efficiency are also implemented in VANETs, yet the cloud based operation significantly enhances the intelligence, and usefulness of these applications. This is due to the advancement of computing power in applications operating through cloud support, for computation and traffic data. Some of the smart applications include real time traffic forecasting, smart toll collection through car payment, and smart challan for traffic rule violation, ad hoc multimedia sharing, smart black-box, and smart emergency call.

In terms of protocols perspective, resource handler protocol IEEE 1609.1 of WAVE is considered for efficient resource management among smart applications. Apart from this, the business models related to advertisement, sale, service, and insurance are considered. The protocol development to support traffic data based business models is an open research theme in CC-V.

3. ELEMENT

In this section, three major elements which formed CC-V are explored focusing on networking aspect of proposed layered architecture (see Fig. 2). In a broader physical structural point of view, the components including vehicle, connection, and computation represent the networking aspects of CC-V. The vehicles are end users, and thus, the services are delivered at vehicles. This component in is closely related to the perception layer of the proposed architecture. This is due to different types of sensors for monitoring speed, direction, and position which are considered to be attached to the vehicles. The second component namely, connection include network or communication devices of the heterogeneous networks. A heterogeneous network including VANETs, Wi-Fi, 4G/LTE is primarily considered. This component is closely related with the coordination layer of the proposed architecture. The last component named computation refers to the computing and storage devices, responsible for the efficient processing of big traffic data, and inferring intelligent decisions. This last component is closely related to the artificial intelligence layer of the proposed layered architecture. This is due to the related functionalities of the layer. The relationship among these network components is potential due to the collective operation requirement for the services offered by the architecture. The vehicle to connection relationship determines the efficiency of delivery, and acceptance of the services provided. The connection and computation determine the quality of information of the services. Each element and their role in CC-V are defined below.
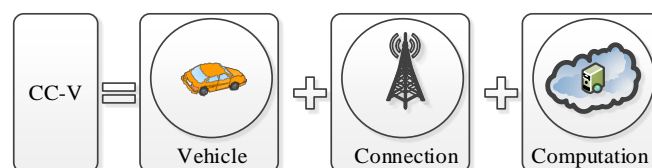

Figure 2. The network component of CC-V

3.1 Vehicle

The vehicles have several in-built technologies and resources, which are underutilized in traditional vehicular communication architecture. The technologies and resources include Telematics Wire Devices (TWD), Global Positioning System (GPS), sensors, Dedicated Short Range Communication (DSRC), actuators, computer and smartphones. The utilization of these resources can be improved through a cooperative collaborative network architecture. The underutilization of the resources motivates the concept of CC-V. This is due to the fact that the vehicles do not have some of the challenges of mobile devices in Mobile Cloud Computing (MCC), such as, lower computing capability, smaller memory size and battery life. The resources of vehicles can be shared under the framework of VCC at many places while travelling. It include parking lot, garage and traffic light. In case of extensive computing need for longer duration, vehicle's in-built technologies can be utilized for establishing durable connection to a conventional cloud. The communication is known as VuC. For both the cases, VCC and VuC, vehicles equipped with modern communication technologies are one of the most important constituent.

3.2 Connection

The connection refers to the network or communication devices of the heterogeneous networks architecture considered in CC-V. The network devices are utilized to establish reliable communication between vehicles and cloud. In the case of VuC, the connection is either a direct communication between vehicles and cloud infrastructure, or a multi-hop communication using Road Side Units (RSUs) with vehicles. In the case of VCC, connection is mostly direct communication between a vehicle and vehicular cloud infrastructure. The connection also defines Services Level Agreement (SLA) between a vehicular client and cloud infrastructure. It is due to the fact that SLA represents the level of QoS of an application based on the architecture of CC-V. Therefore, connection determines delivery and acceptances of the services.

3.3 Computation

The computation refers to the computing and storage devices where big traffic data are processed and intelligent decisions are inferred. The computation is broadly divided into three models including computation provider, computation consumer, and hybrid. In computation provider model, the vehicles are required to register with service provider for availing their vehicular resources to cloud computing architecture using SLA. In computation consumer model, vehicles need to register for utilizing the cloud computing services as their own resources. In the case of hybrid model, vehicles need to register for both as a provider and as a consumer. The provider model would generate revenue by improving resources utilization. The consumer model would enhance computing capability of vehicles by utilizing cloud infrastructure. The hybrid model would be more complex due to the need for maintaining provider or consumer state for each vehicle.

4. CLOUD COMPUTING IN VANETS

In this section, cloud computing in VANETs (CC-V) is qualitatively reviewed on the basis of a taxonomy depicted in Fig 3. Cloud computing is an emerging research theme in VANETs. It is evolving due to the growing need of higher computing capability at vehicles to expand the various commercial services currently available in Internet to VANETs. CC-V has four major issues, namely, design of architecture, data dissemination, security, and applications. Each issue has been investigated in several directions which are qualitatively, and critically reviewed in following sections.
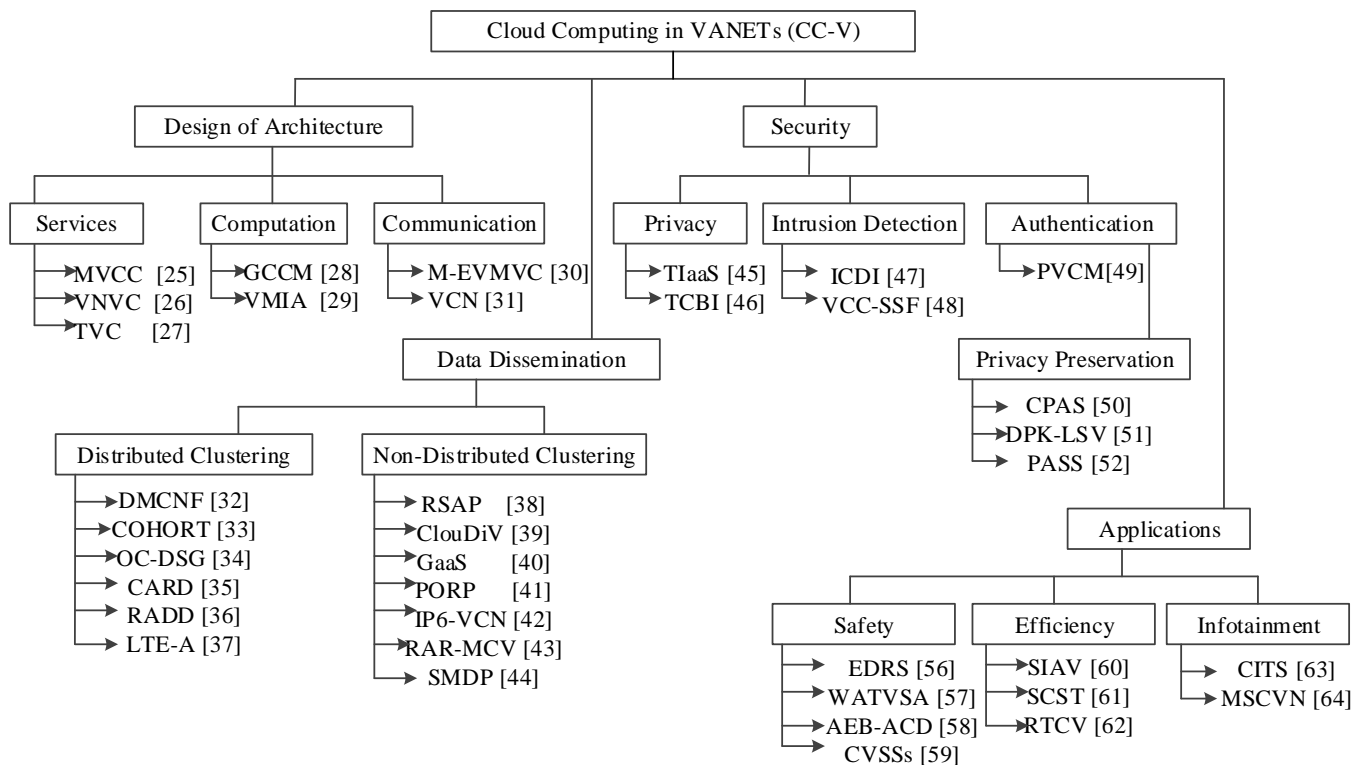

Figure 3. The taxonomy of CC-V

4.1 Design of Architecture

In this section, related literature on designing architecture to access cloud computing services in VANETs is reviewed. The challenges of lower utilization of VANETs resources, and unstandardized architecture of CC-V are the main focus in literature. The design of architecture has been divided into three categories including services, computation and communication. Architectures focusing on how to utilize vehicular resources as cloud resources has been categorized in services. Architectures focusing on how to utilize traditional cloud computing services in vehicles, and how to improve communication between traditional cloud and vehicular cloud, are categorized in computation and communication, respectively.

4.1.1 Service

In [25], a concept that Merges VANETs with Cloud Computing (MVCC) has been suggested to address underutilization of vehicles' on-board devices and lack of standard architecture for VCC. The on-board devices have the capabilities including computation, communication and storage of information. An architecture for cloud computing in vehicular communication has been defined and further divided into three architectural frameworks including VCC, VuC, and hybrid vehicular cloud (see Fig. 4). In addition, security and privacy issues related to VCC are outlined. However, elements of the cloud computing in vehicular communication are not explicitly defined. The protocols and functions of the architecture are not considered in terms of applications, network coordination and intelligence layer of the proposed CC-V layered architecture.

The Paradigm shift from Vehicular Ad hoc Networks to VANET-based Clouds (VNVC) [26] is an extension of the work in MVCC. The VNCN proposed an architecture including communication paradigm, cloud services, computation, and traffic information dissemination through cloud architecture. The major contribution of VNCN is traffic information as a service. It handles complex traffic information computations using cloud. It also provides services including big traffic data analysis, remote configuration, car performance checking, smart location-based advertisements and vehicle witnesses, its application can be related to smart application and artificial intelligence layer of the proposed CC-V layered architecture. Fig. 5 shows a network model for the traffic information as a service. In traffic information dissemination through cloud, moving vehicles serve as cooperative forwarder to send coarse-grained information to the cloud, and to receive fined-grained information from the cloud. The functional modules including Cloud Processing Module (CPM), Cloud Knowledge Base (CKB) and, Cloud Decision Module (CDM) and authenticators have been considered at the cloud layer, this is also applicable to artificial intelligence layer of the CC-V layered architecture. However, some performance metrics have been measured, yet the distance between communicating vehicles and infrastructure, and the delay in connectivity are not considered.

Figure 4. The Three Computing architecture for Cloud Computing in Vehicular Communication

Another idea of Taking VANETs to the Clouds (TVC) has been suggested by Olariu et al. [27] to address the problem of standardization of VANETs to cloud integration architecture. Further, privacy and security issues related to integration of VANETs to the cloud have been outlined. The architecture includes two different services, namely, network as a services, and storage as a services. The cloud computing vehicular communication scenarios for the TVC have been depicted in Fig. 6. It shows the network as a service and storage as a service concepts in vehicular environment. From the authors' deduction network as a service, is more suitable for cloud computing in vehicular communication due to the consideration of 3G or Wi-Fi based Internet connection at vehicles. Therefore, internet connections can be used by passengers on-board to surf Internet. SaaS is also applicable in cloud computing over vehicular communication, since vehicles are considered interconnected to form local clouds. These vehicles can share their memory, and processor for storage, and computation of

large data. The implementation of services of traditional cloud computing has been theoretically presented for the vehicular cloud. Thus, the investigation can be considered very close to the functions considered under artificial intelligence and smart application layers. Although the technical detail of the implementations has not been presented.
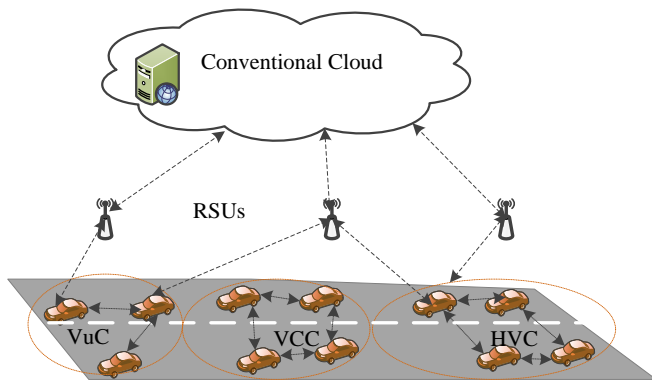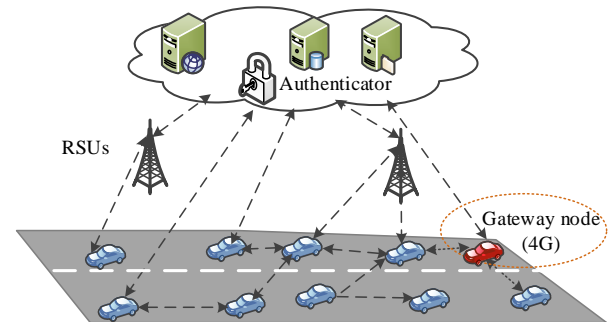

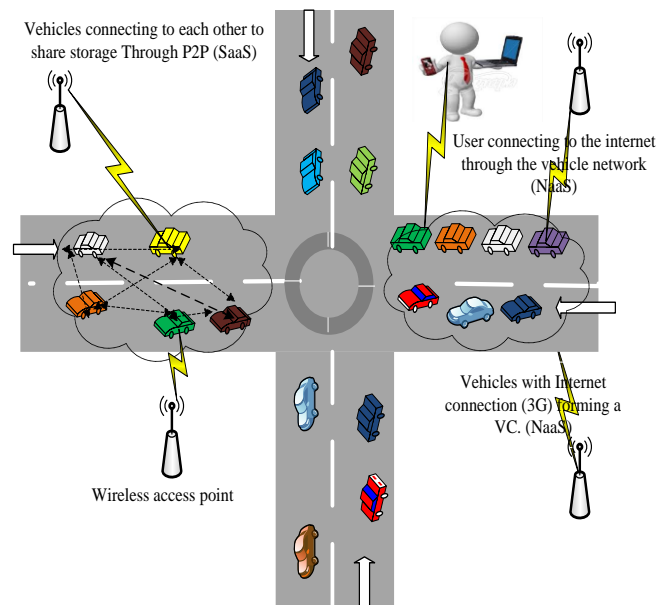**Figure 5. The Network Model for Traffic Information as a Service**

Figure 6. The Network as a Service and Storage as a Service for Cloud Computing in Vehicular Communication

4.1.2 Computation

In [28], a Generic Cloud Computing Model (GCCM) for VANETs has been suggested to enhance the availability of on-board system for other client vehicles. VANETs cloud model has been unveiled which consist of two concepts including permanent and temporary cloud layer model. The permanent cloud layer serve as conventional cloud, and the temporary cloud serve as vehicular cloud computing. The permanent cloud layer is the same as the tradition cloud which handles related functions of smart applications and artificial intelligence layer of the CC-V layered architecture. While the temporary cloud can be related to the perception layer in the proposed CC-V layered architecture. The infrastructure components are grouped into three layers including client, communication, and cloud. The novel intelligent transportation system applications supported by VANETs cloud include business and research

applications, vehicular software, web services and processing cloud backup, and safety applications. However, protocols and functions of the architecture are not defined.

In Yan et al. [29] proposed a Vehicular Cyber-Physical Systems (VCPS) based on Mobile Integrated Architecture (VMIA). The system addresses the increasing demand from mobile cloud computing users to access vehicular cloud computing services. VMIA consist of the conceptual architecture for VCPS with mobile cloud computing capabilities (See Fig. 7). VMIA is the integration of VCPS and mobile cloud computing to provide mobility support to users. Cloud supported components are grouped into traffic-aware mobile geographic information system and dynamic vehicle routing algorithm. In order to provide driving assistance, a paradigm called traffic-aware mobile geographical information system with traffic cloud support system has been discussed. The functions of mobile geographical information system can be used for traffic cloud support by incorporating traffic dynamics with base map management. A decentralized and proactive dynamic vehicle routing algorithm has been developed to enables drivers to self-organize the traffic and shift the system state from either dynamic all-or-nothing or dynamic user equilibrium to dynamic system optimal. VCPS based on mobile cloud computing support architecture have been explained. The CC-V elements are related to VMIA in terms of mobile phone devices which are situated in the vehicle, the communication between mobile device and the cloud is aided by connection and the computation is carried out at the mobile cloud computing layer. The VMIA findings can be considered very close to the functions of smart applications and artificial intelligence layer of the CCV layered architecture. Nevertheless, frequent intermittent connection might arise due to high mobility of vehicles. Security related issues and implementation of the architecture has not been dealt with.
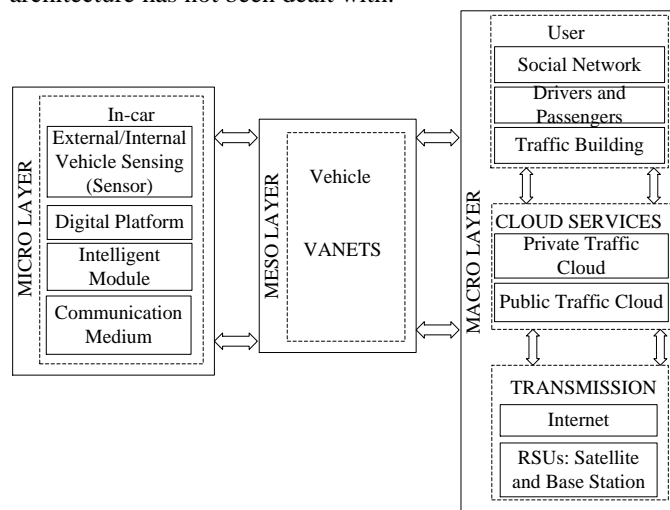

Figure 7. The VMIA

4.1.3 Communication

In [30], an idea of whether to Migrate or not has been investigated, by Exploring Virtual machine Migration in roadside cloudlet-based Vehicular Cloud (M-EVMVC). The concepts is to address the challenges of sharing resources with high mobile vehicles. The roadside cloudlet based vehicular cloud architecture, and two-phase polynomial heuristic algorithm have been presented. The problem has been formulated as a mixed-integer quadratic programming problem. The programming problem is based on four constrains including path selection, virtual machine placement, resource capacity and link capacity. The virtual machine placement issue has addressed using static offline placement approach. Virtual machine migration and system model of cloud computing in vehicular communication has been explored. The performance of the two algorithms has been evaluated to test the effect of cost on the density and resource requirement of virtual machines, and roadside cloudlets, and traffic rate requirement of virtual machine. Although, implementation has been carried-out, yet well-known network simulator has not been used for implementing the architecture in order to evaluate its effectiveness. The virtual machine migration is closely related to the mentioned CC-V layered architecture in terms of artificial intelligence and perception layer, since it deals with migration technology of traditional cloud.

Vehicular Cloud Networking, (VCN), and design principles have been suggested to address the need for intelligent computation for safety and comfort applications in vehicular environment [31]. The VCN architectural formation can be seen in relation to smart applications and artificial intelligence layer of the CC-V layered architecture. VCN architecture and design principles have been discussed. The VCN architecture is constituted based on cloud computing for vehicular communication and information centric networking for handling safety, comfort and privacy. In VCN routing, it does not need to know who sent the information. Further, new model for application and networking has been discussed. However, the elements are not clearly defined in terms of the CC-V. Also, functions and protocols are not considered.

4.1.4 Comparative Discussion on Design of Architecture

The aforementioned literature review on design of architecture is summarized in Table 1. The summary is based on the parameters including contribution, type of architecture, technique, implementation and remarks. The contribution points out the progressive impact of the articles on the research theme of architecture design for CC-V. The architecture determines the category from the three types including VuC, VCC, and HVC. The techniques identifies the approach followed for addressing the raised issue. The implementation shows implementation tools and performance metric. The critical remarks have been also made. A comparison is also presented in Table 2. The comparison is based on three parameters including technique, architecture and implementation. The technique is defined using conceptual model, complete framework and algorithm. The architecture is defined using VuC, VCC, and HVC. The summary and comparative assessment attest that M-EVMVC [30] has more viable architecture than other proposed architectures, when related to the proposed CC-V layered architecture, CC-V elements, better algorithm with complexity analysis, implementation proof with wide range of performance metrics

Table 1. The Summary of related literatures on design of architecture

Protocols	Contribution	Architectures	Techniques	Implementation	Remarks
MVCC [25]	VANETs and cloud	VuC, VCC and HVC	Architecture design	Not considered	Intermittent connectivity not addressed
VNVC [26]	TIaaS	VuC	Model and Architecture	NS-2.34, TranNS and SUMO	Communication delay not considered
TVC [27]	NaaS, SaaS	VCC	Architecture design	Not considered	Practically not tested
GCCM [28]	Computing Model	VuC	Model design	Not considered	Model is not associated with any architecture
VMIA [29]	VMIA support Architecture	VuC	Architecture design	Not considered	security issue is idea not outlined
M-EVMVC [30]	Algorithms for cloudlet	VCC	Algorithms development	Own Network simulator	Standard simulation tool not considered
VCN [31]	VCN design	VCC	Architecture design	Not considered	Practically not tested

Table 2: A comparative assessment on design of architecture

Protocol	Techniques			Architectures			IM
	CM	CF	AL	VuC	VCC	HVC	
MVCC [25]		√		√	√	√	
VNVC [26]	√	√		√			√
TVC [27]		√			√		
GCCM [28]	√			√			
VMIA [29]		√		√			
M-EVMVC [30]		√	√	√			√
VCN [31]		√			√		

NOTE: CM=Conceptual Model, CF= Complete Framework, AL=Algorithm, IM=Implementation.   √=Yes and ×=No

4.2 Data Dissemination

In CC-V, clustering is the preferred option for data dissemination among vehicles. This is due to the higher possibility of cloud based resource sharing while disseminating data in case of clustering. In this section, related literature on designing clustering schemes for transmitting data in CC-V is critically explored and comparatively assessed.

4.2.1 Distributed Clustering

A Distributed Multi-hop Clustering algorithm based on Neighborhood Follow (DMCNF) has been presented to enhance robustness in clustering algorithms [32]. The DMCNF basically focuses on how the vehicular cloud nodes communicate among each other to improve efficiency. Hence, its functional suitability is in co-ordination and artificial intelligence layer of the proposed CC-V layered architecture. It is a routing scheme that uses proactive and shortest path methods. An algorithm based on one-hop neighborhood follow strategy has been suggested. The algorithm considers three factors for choosing a follow vehicle including relative mobility, current number of follows and history of cluster. In proactive clustering scheme, high signaling load overhead might occur due to the frequent update of its follow information, and dynamic change of node's state. In this work, quality of network at each node has not been considered during the selection of follow node. The aforementioned elements of CC-V is the constituent of the DMCNF, but has not been defined in this study.

A Cluster based vehicular cloud system with learning-based Resource management (COHORT) has been presented.

COHORT deals the challenges faced during deployment of new applications, and advancement of intelligent transport system services [33]. An example of cluster-based VCC system and case scenario for resource management issue is depicted in Fig. 8. A VCC system, q-learning technique and queuing strategies have been discussed. VCC system has been designed to conform to clustering procedures. It then further present the resource limitation difficulties, by grouping vehicles and cooperatively providing the resources to the needy vehicles. In essence, the clustering structure technique has made flexible using fuzzy logic in the Cluster Head (CH) selection process. Frequent broadcasting and updating of routing table information might cause high signaling loads on the network. Security challenges in respect to the cluster based architecture have not been considered. COHORT can be best related to artificial intelligence and smart applications layer of the CC-V layered architecture considered in terms of functions and its protocols.
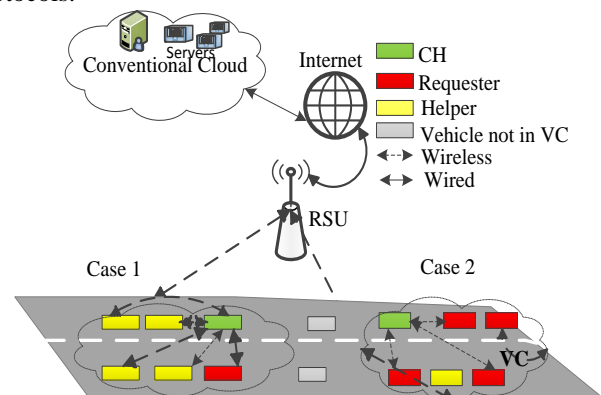

Figure 8. The Cluster-Based VCC architecture

COHORT resource management issues. Case 1: vehicle Requester sends a request to CH. Four helpers' vehicle are available and CH should select one of them. Case 2: Four requester vehicles have different requests and CH should setup a priority queue to allocate limited resources to them, with only one helper.

Kumar et al. [34] has suggested an Optimized Clustering for Data forwarding using Stochastic coalition Game in vehicular cyber-physical systems (OC-DSG) to address the issue of lesser contact time for vehicles with access points. A stochastic

coalition game for an optimized clustering and an algorithm for data dissemination in vehicular cyber physical system environment have been developed. Stochastic coalition game is employed as a selection strategy in vehicular cyber physical system. The Vehicles are represented as players in the coalition game. A vehicle accesses a fixed number of resources from the cloud. Learning automata techniques is utilized in vehicles to gather and process information from the surrounding based on pre-stated policies. The optimization clustering scheme is typically related to co-ordination layer of the CC-V layered architecture, since it deals with communication between clustered node and RSUs. However, the authors have claimed through the evaluation of some performance metrics, that the scheme outperformed the existing state-of-the-art schemes. Implementation of the CC-V layered architecture will enhance performance of the clustering techniques employed.

A bayesian coalition game for Contention-Aware Reliable Data (CARD) forwarding in vehicular mobile cloud addresses the issue of performance degradation due to the unicast sender-based data forwarding [35]. The problem of reliable data forwarding is formulated as Bayesian coalition game using an adaptive learning automata concept. An adaptive learning automata-based contention aware data forwarding algorithms for critical applications in the vehicular mobile cloud has been developed. The approach is based on co-ordination and artificial intelligence layer of proposed the CC-V layered architecture. The vehicles represent the players in the game. These players are used for taking adaptive decisions with regards to effective and reliable data forwarding. Each player monitors the moves of the other players in the game for reliable data forwarding. Additionally, security issues has not been considered. The implementation environment has not been discussed.

In [36], a Replication-Aware Data Dissemination (RADD) is presented for vehicular ad hoc networks using location prediction to address the challenges of disconnection due to high node mobility. The new replication-aware scheme has been suggested to estimate location of nodes. An algorithm for position estimation, accessing and route in messages from remote vehicles to the destination have been developed. The bloom filters are used for searching suitable vehicles for replica assignment. It makes searching faster and improves the total performance of RADD. Additionally, Radio Frequency IDentification (RFID) tags are employed on the vehicles and RSUs serves as RFID reader to gather data from these tags. The tags data serve as location information for short range communication in case of global positioning system failure. The RADD is closely related to the co-ordination and perception layer of the CC-V layered architecture because it deals with connectivity of vehicular nodes. The security issues of replication-aware data dissemination has not been explored. Enabling cooperative relaying in VANETs cloud over LTE-A networks has addressed connectivity and device heterogeneity issues in high populated urban area [37]. A cooperative vehicular relaying transmission scheme has been designed. The scheme contribute towards the formation of an advanced heterogeneous telecommunication network. It provides increased networking capabilities for heavily populated urban areas. This scheme made use of vehicles equipped with low elevation antennas, and short and medium-range wireless communication technologies. The authors claimed that a reasonable diversity gains and minimized error rate were achievable. Furthermore, there is a significant reduction in the required transmitting energy when compared to the existing transmission scheme, and also improvement in distance area coverage. Despite of enhancing connectivity and heterogeneity, low density and rural environment for VANETs setting have not been considered. The investigations can be considered very close to the functions considered under co-ordination and perception layer of the CC-V layered architecture for cooperative relaying transmission in VANETs cloud.

4.2.2 Non-Distributed Clustering

A data dissemination model for cloud enabled VANETs using in-vehicular resource system based on Road Side Access Point (RSAP) has been suggested to handle connectivity and resources availability issues [38]. The technology of RSAP is closely applicable to the co-ordination and perception layer of the CC-V layered architecture since it functions as networking support layer. Different services and applications of VANETs including connectivity have been pointed through RSAP. The deployment of cloud, need of VCC service provider, and classification of VCC have been discussed. The classification of VCC includes private or public, dynamic or static, in-vehicular or out-of-vehicle, network as a service or communication as a service. It has been further divided as data centric or address centric, distributed or hybrid. The classification is based on the factors including participation, mobility, integration point, content management criteria, and, integration with backbone networks. However, security issues with regards to the outlined model are not discussed.

Cloud computing-based message Dissemination protocol for Vehicular ad hoc networks (ClouDiv) has been presented to deal with issue of intermittent connectivity due to the higher speed of vehicles, and their restricted capacity in terms, of bandwidth [39]. Fig. 9 shows data center and VANETs node's routing table in ClouDiV. ClouDiv has provided an adaptive dissemination of safety and non-safety messages through cloud computing architecture. In ClouDiV dissemination, a proactive routing approach for data centers and reactive approach for vehicle have been adopted. Stochastic routing method has been used during dissemination. Hence, since both proactive and reactive method are employed, high signaling load might occur due to the adoption of proactive routing table discovery. The data center have to update the table frequently. ClouDiV is closely related to functions of co-ordination layer of the proposed CC-V layered architecture. Quality of Network (QoN) at each vehicular node has not been considered.
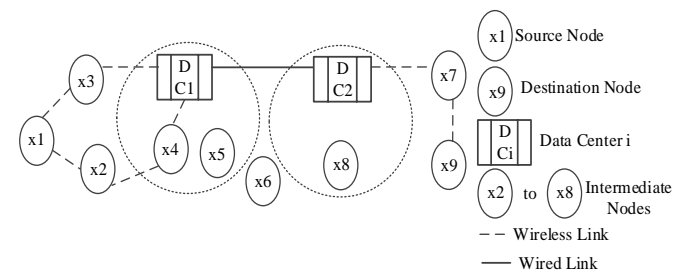

Figure 9. Data center view for ClodDiV

Cloud-supported seamless Internet access in intelligent transportation system has been recommended for accessing

high quality ITS services [40]. Cloud supported gateway model, Gateway as a Services (GaaS), and a link lifetime prediction scheme have been developed. GaaS model is depicted in Fig. 10. GaaS has been divided into two gateways including mobile gateway and static gateway. In mobile gateway, access point is mounted on high mobility vehicles such as public bus in the city. It serves as gateway for other vehicles to connect to the cloud. In static gateway, the conventional RSUs serve as access point, RSU are used as gateway for vehicles to connect to the Internet. Link life time prediction scheme considers time of entering or exiting from the gateway coverage. In this scheme, qualitative packet delivery has been achieved since link lifetime is consideration. However, fault detection has become complex due to large numbers of gateways in the network setup. The GaaS model and link lifetime prediction scheme are nearly related to the functions considered under co-ordination and perception layer of the CC-V layered architecture due to the handoff operation and location based networking support.
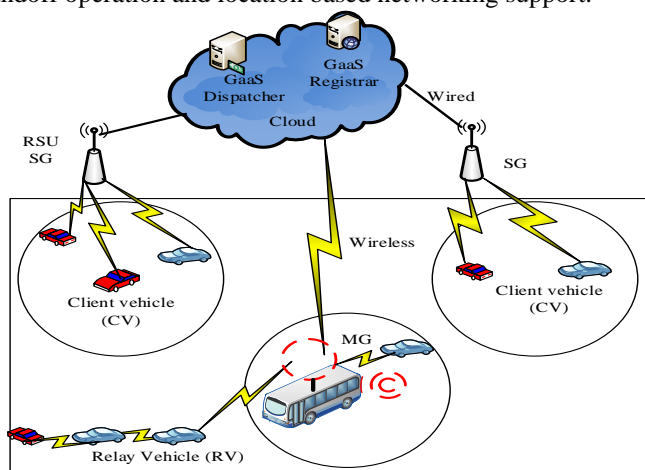

Figure10. The GaaS System Model

Ikeda et al. [41] has suggested a Performance of Optimized link state Routing Protocol (PORP) for video streaming application in vehicular cloud computing. PORP has addressed the challenges of advancement in communication and the need of efficient connection. Network as a service architecture for VANET cloud computing has been considered to investigate the performance of Optimized Link State Routing (OLSR) protocol for video streaming application. OLSR has used proactive and shortest path approaches which might cause high signaling load. It is required to measure signal strength at each node to choose best path for routing. The PORP protocol can be considered under the functions of co-ordination and artificial intelligence layer in terms of the CC-V layered architecture.

IPv6-based Vehicular Cloud Networking (IP6-VCN) has been suggested in [42]. The flooding techniques adopted in most of the recent studies tends to increases the cost of content acquisition due to the content-centric approach for dissemination in VCC. The vehicular cloud domain system, vehicular cloud networking and performance evaluation has been discussed. Vehicular cloud networking includes addressing structure, vehicular cloud construction, vehicular cloud management and content acquisition. The addressing structure creates relationship between IP and content data for effective routing. The vehicular cloud domain system effectively minimizes the cost of content acquisition. However,

in this scheme, communication between V2I has not been considered for assisting the content sharing and acquisition. The IP-VCN can be related to the aforementioned functions of co-ordination layer of the CC-V layered architecture.

In [43], a Reliable Adaptive Resource Management for cognitive Cloud Vehicular networks (RAR-MCV) has been suggested to address limited computing capability and energy of smartphones in car in order to utilize the available V2I Wi-Fi connections for traffic data offloading [43]. An optimal joint controller and related supporting access protocol has been discussed. The protocols has been claimed to be adaptive, scalable and distributive. The developed optimal controller dynamically manages the access time windows at the serving RSUs. It also manages the access rates and traffic flows at the served VCC system in a distributed and scalable way. Its implementation complexity is fully independent from the number of the serving RSUs, and served VCC system. Nevertheless, optimized routing management and implementation of the concept has not been considered. The findings can be closely related under the functions of co-ordination and artificial intelligence layer of the proposed CC-V layered architecture. The basic elements of the RAR-MCV have not been adequately explored. However, our proposed CC-V elements can be applicable in this study.

Zheng et al. [44] proposed a Semi-Markov Decision Process (SMDP) based resource allocation in vehicular cloud computing system in order address underutilization of vehicular resource. The SMDP is closely suitable in relation to the aforementioned CC-V layered architecture in terms of artificial intelligence and perception layer. A computation resource allocation scheme has been presented. Further, the resource allocation problem has been formulated as an infinite horizon problem for SMDP. SMDP defines state space, action space, reward model, and transition probability distribution of the VCC system. In order to develop optimal scheme, iteration algorithm has been used to define the action taken under a specific state. In addition, resource allocation and decision-making schemes, and a reward system were developed. Authors claimed that reasonable performance gain has been achieved by the SMDP-based scheme within the permissible complexity. However, effects of tolerance parameter to the optimal scheme has not been investigated.

4.2.3 Comparative Discussion on Data Dissemination

The above reviewed literature on data dissemination in CC-V focusing on clustering approach, is summarized in Table 3. The summary considers the parameters including contribution, type of architecture, technique, implementation and remarks. The contribution represents the progressive impact of the articles on the design of data dissemination technique for CC-V.

The architecture determines the category from the three types including VuC, VCC, and HVC. The technique defines the approach followed for addressing the raised issue. The implementation shows simulation tools and performance metric. The critical remarks have been also made. A comparative study is also presented in Table 4. The comparative study is based on three parameters including technique, architecture and implementation. The technique is defined using conceptual model, complete framework and algorithm. The architecture is defined using VuC, VCC, and

HVC. The summary and comparative study of data dissemination techniques suggest that RAR-MVC [43] is more feasible and better data dissemination technique. RAR-MCV considered Markovian random walk as its mathematical modelling technique which effectively optimizes routing objectives. The performance evaluation is widely explored with range of metrics and environments. Both the distributive and non-distributive clustering can be efficiently enhanced based on co-ordination, artificial intelligence and perception layer of our proposed CC-V layered architecture. The co-ordination layer will handle clustering and connectivity issues. The artificial intelligence layer will handle vehicle clustering in order to perform cloud computing operations. The perception layer is linked with the in-vehicular devices and vehicular node itself.

Table 3: The Summary of related literatures on data dissemination

Protocols	Contribution	Architecture	Techniques	Implementation	Remarks
DMCNF [32]	Multi-hop clustering	HVC	Follow algorithm	NS-2 and VanetMobiSim	Signaling overhead
COHORT [33]	Q-learning, Queuing	HVC	Fuzzy logic	OMNet++, SUMO and Veins	Framework security issue
OC-DSCGV [34]	Algorithm for system	VuC	Stochastic coalition game	NS-2 with SUMO	Urban scenario not considered
CARD [35]	Contention-aware forwarding	VuC	Learning automata	VANET MobiSim	Security in forwarding issue
RADD [36]	Replication-aware communication	VCC	Algorithm design	NS-2 and SUMO	Replication overhead
LTE-A [37]	Relay node selection	VCC	Pre-coding transmission	Monte Carlo simulator	Standard simulator not considered
RSAP [38]	Optimizing resource sharing	VCC	Mathematical model	OPNET 17.5	Theoretical model validation not performed
ClouDiV [39]	Dissemination protocol	VuC	Proactive and reactive routing	NS-2	QoS of each routing path issue
GaaS [40]	Link life time prediction	VuC	Mathematical prediction Model	NS-2	complexity not analyzed
PORP [41]	Impact of OLSR in video dissemination	VuC	OLSR routing protocol	Scernagie network	Signaling overhead.
IP6-VCN [42]	Architecture with IPv6	VCC	System level design	NS-2.	IP6 enabled access point issue
RAR-MCV [43]	Distributed and adaptive resource management	VuC	Markovian random model	Mathematical tool	Routing optimization issue
SMDP [44]	Intelligent decision aided resource allocation	HVC	Algorithm design	Modeling tool	Impact of parameters on decision issue

Table 4: A comparative assessment on data dissemination

Protocol	Techniques			Architectures			IM
	CM	CF	AL	VuC	VCC	HVC	
DMCNF [32]			✓			✓	✓
COHORT [33]		✓	✓			✓	✓
OC-DSG [34]	✓		✓	✓			✓
CARD [35]	✓		✓	✓			✓
RADD [36]			✓		✓		✓
LTE-A [37]	✓		✓		✓		✓
RSAP [38]	✓	✓			✓		✓
ClouDiV [39]			✓	✓			✓
GaaS [40]	✓		✓	✓			✓
PORP [41]			✓	✓			✓
IP6-VCN [42]		✓			✓		✓
RAR-MCV [43]	✓	✓	✓	✓			✓
SMDP [44]	✓		✓			✓	

NOTE: CM=Conceptual Model, CF= Complete Framework, AL=Algorithm, IM=Implementation.   √=Yes and ×=No

4.3 Security

The major challenges of security in CC-V includes privacy, intrusion detection, and authentication. The communication with neighbor vehicles using location, speed and direction information, without unfolding the identity of each other, is privacy in CC-V. The identification of uncooperative neighbor vehicle, is intrusion detections. The verification of neighbor vehicle base on some reputation, is authentication in CC-V. All these major CC-V security issues can be improved on, if the CC-V layered architecture is critically analyzed and incorporated with the security model. Security challenges of smart applications is basically authentication issues including automatic safety, information management and services authentication. For artificial intelligence the major issues with security is in intrusion detection of servers and data centers or vehicles which forms cloud when a computing request from external client is being sent to the machines. Co-ordination layer can be used as channel for intrusion and bridging of authentication process. Hence, intrusion detection and authentication issues can be tackled effectively at this layer. The perception layer constitute in-vehicle devices and the vehicle nodes, thus, the major challenge in this layer is privacy and intrusion detection. With implementation of the CC-V layered architecture a more secured CC-V can be achieved.

4.3.1 Privacy

Hussain et al. [45] suggested a Secure and privacy-aware Traffic information as a Service (TIaaS) for VANET-based clouds to address the vehicle user privacy issue. The privacy issue is one of the major concern why many vehicle users don't want to take part in the information sharing among vehicles. Hence, a privacy aware TIaaS has been discussed. The network

model of TIaaS is shown in Fig. 11. The privacy issues causes lower usage of VANETs infrastructure including communication, computation and on-board storage. A revocation mechanism, TIaaS thin-client concept for vehicles, and efficient mobility vectors framework have been designed. TIaaS model has used VuC framework. It provided fine-grained traffic information to vehicles from the cloud due to the subscriber cooperation with the cloud in secure and privacy-preserving way. Despite its strength in concealing location information, it might take longer processing time due to the encryption scheme adopted. The TIaaS is a security scheme that is best applicable under the functions of perception and co-ordination layer of the CC-V layered architecture. Implementation is required to test feasibility of the scheme.
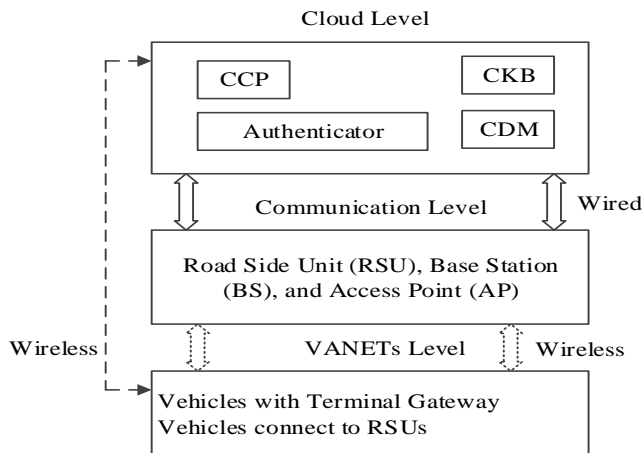

Figure 11. The TIaaS Network Model

In [46], a secure and privacy preserving protocol for cloud-based vehicular Delay Tolerance Networks (DTNs) has been presented to address the issue of privacy in incentive system and packet forwarding protocol. Network model for vehicular DTNs is depicted in Fig. 12. A Threshold Credit based Incentive (TCBI) mechanism has been designed for privacy preserving packet forwarding. TCBI encourages vehicles to cooperate with each other by calculating security and privacy and sharing resources with a certain rule. The privacy preserving packet forwarding protocol has been used to address the challenges of layer attack by contracting out privacy preserving transmission proof generation for resource-constrained vehicles. In TCBI, the vehicular privacy is well secured from both the cloud and transportation manager for performing any one-way trap-door function. The failure at either cloud or transportation manager side might hinder communication of the vehicles. As discussed in the proposed CC-V layered architecture, the layers function closely related to The TCBI are perception and artificial intelligence layer.
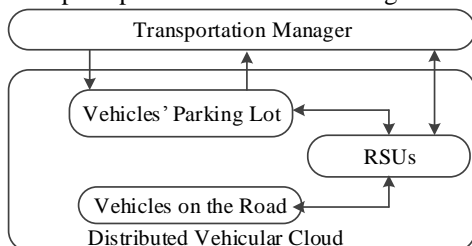

Figure 12. The Network Model for Vehicular DTN

4.3.2 Intrusion Detection

An Intelligent Clustering scheme for Distributed Intrusion (ICDI) detection in vehicular cloud computing has been suggested to address the issue of security i.e. alteration and misuse of information in VCC [47]. A network module of ICDI is depicted in Fig. 13. A learning automata-assisted distributive intrusion detection system has been developed. The system is based on clustering, standard cryptographic techniques and reward penalty stochastic scheme. The system takes intelligent decision, and uses pseudo-dynamic clustering technique to select cluster head, and then determine the cluster structure. The cluster head handles well-organized dissemination of information, and storage through cloud based infrastructure. However, to secure the learning automata system from malicious vehicles, a standard cryptographic techniques has been employed. Nevertheless, a lower processing speed and complexity issue might occur due to the complex cryptographic approach, and dynamic nature of the system. The intrusion detection approach in ICDI is relevant to the functions under artificial intelligence and co-ordination layer of the CC-V layered architecture in term of efficient intrusion detection implementation.
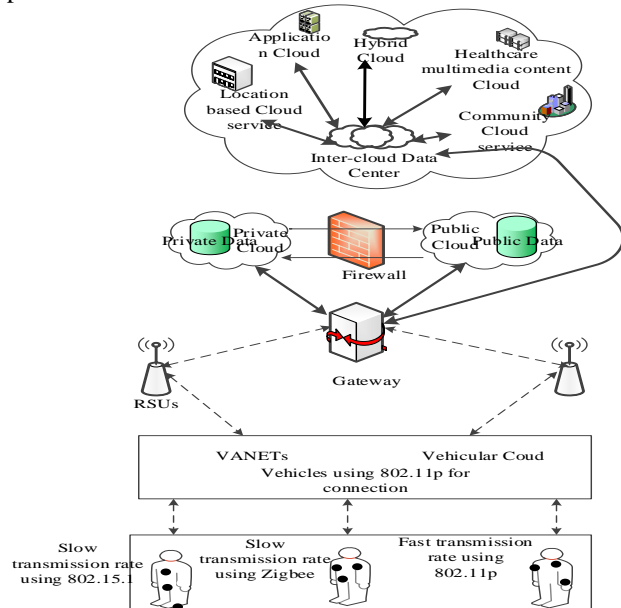

Figure 13. The Network Model for ICDI

Kang et al. [48] suggested a Vehicular Cloud Computing Service oriented Security Framework (VCC-SSF) to solve the challenges of insufficient internal or external security in vehicles' infrastructure, and information leakage from sensors attached to the vehicles. Framework for VCC-SSF has been shown in Fig. 14. The suggested framework has been used to handle user oriented payment, and accident avoidance management services. Furthermore, the framework has provided encryption, authentication, access control, confidentiality, integrity and privacy protection of personal information related to users and vehicles. Accident avoidance management service uses VCC model. The architecture consists of two models. One for before accident and another for after accident. The before accident model has utilized sensors attached with vehicles to monitor the status of driver's health and driving capabilities. However, this framework might not be

economically viable due to the higher requirements and complexity. The findings can be considered very close to the functions employed under smart applications, artificial intelligence and co-ordination layers of the CC-V layered architecture. They can be applied in implementation of the VCC-SSF.
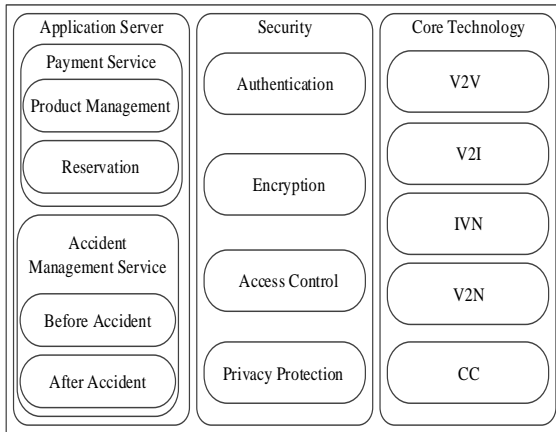

Figure 14. The VCC-SSF Framework

4.3.3 Authentication

Protecting Vehicular Cloud against Malicious (PVCM) nodes using zone authorities has been suggested to address the issues of weak protection of VCC, and threats to data, resources and services [49]. A zone authority framework has been depicted in Fig. 15. A secured framework that uses key management and revocation technique to secure VCC from malicious nodes have been presented. The framework is a decentralized one. It has used multiple zone authorities. Each zone authority manages an area called zone which consist of RSUs, vehicles and the clients at that zone. Every zone authority serves as a gateway which authenticate actions of that zone. It manages the service requests and the data flow and preserves the privacy of the cloud entities including vehicles and the client. In this kind of node protection, too many authentications occur while moving from one zone to another. This might degrade the communication between vehicles. Implementation is also required to examine suitability of the framework. The investigation can be considered to be nearly to the functions considered under co-ordination and smart application layer of the CC-V layered architecture. The PVCM framework can be improved based on the CC-V layered architecture.

4.3.3.1 Privacy Preserving Authentication

The privacy preserving authentication is also one of the major issue in CC-V under privacy and security issues. Privacy preserving authentication is broadly divided into three categories including pseudonym changing, silent period and mix zone. Some of the recent advances in these categories are critically reviewed. In [50], A Conditional Privacy-preserving Authentication Scheme (CPAS) for vehicular sensor networks has been suggested to secure communication between vehicle and infrastructure in VANETs. CPAS uses pseudo identity-based signature to secure V2I communication. It enables RSU to validate numerous received signatures in parallel. It significantly reduces the total verification duration. The performance of the CPAS has been investigated in terms of

verification delay. It shows great potentials when compared with ZLLHS. Privacy preserving authentication of V2V communication has not been considered in this work. The co-ordination and perception layer are best suitable for the CPAS scheme when related to functions and its protocol of the CC-V layered architecture.

Lu et al. [51] suggested a Dynamic Privacy-preserving Key management scheme for Location-based Services in VANETs (DPK-LSV) to preserve privacy of vehicles, while improving efficiency of location based services in VANETs [51]. DPK-LSV provides anonymous authentication to vehicles, and enables dual registration detection. The efficient location based service sessions have been used. The service sessions are based on several time slot to hold session key. An integration of dynamic threshold technique with V2V and V2I communication has been performed to accomplish the session key's backward secrecy. The authors claimed about the effectiveness and efficiency of the scheme in relation to fast key update ratio, and low key update delay. A Pseudonymous Authentication Scheme with Strong (PASS) privacy preservation for vehicular communications has been suggested to enhance privacy preservation in vehicle communication [52]. PASS has applied pseudonymous authentication in preserving vehicles privacy. It also supports RSU aided distributed certificate services that allow the vehicles to update the information on road. It has been claimed that PASS outperformed previous schemes in relation to certificate updating overhead, and revocation cost. However, only highway scenario was considered during implementation. From the findings, it demonstrates that PASS is very close to the functions considered under co-ordination and perception layer of the CC-V layered architecture. In DPK-LSV privacy preserving scheme, the functions of co-ordination and perception layer of the CC-V layered architecture are suitable layers that can enhance authentication of the system.
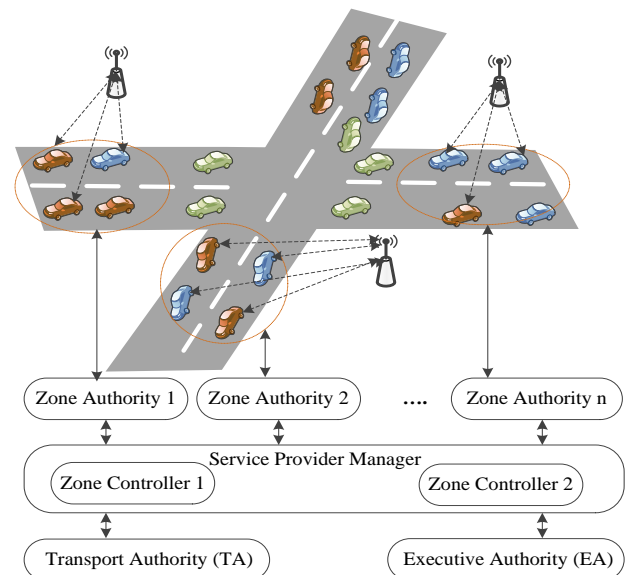

Figure 15. The Zone Authority Framework

4.3.4 Comparative Discussion on Security

The aforementioned literature review on security in CC-V is summarized in Table 5. The summary is based on the parameters including contribution, type of architecture, security technique, implementation and remarks as security holes. The contribution points out the level of security enhancement provided by the articles in CC-V. The architecture determines the applicability of the security technique in the categories including VuC, VCC, and HVC. The technique tells the novel method used for providing security. The implementation shows experimental tools and metric for security attestation. The critical remarks in terms of security holes have been also identified. A comparative investigation is also presented in Table 6. The comparative investigation is based on three parameters including security technique, architecture and implementation. The security technique is defined using the model for security, complete framework and security algorithm. The architecture is defined using VuC, VCC, and HVC. The

summary and comparative investigation of the security techniques affirms that ICDI [47] provides better security and privacy preservation in CC-V environments. The distributed security model is presented in ICDI. All the major CC-V security challenges including privacy, intrusion detection, authentication and privacy preserving authentication can be efficiently enhanced based on smart applications, co-ordination, artificial intelligence and perception layer of our proposed CC-V layered architecture. Authentication and intrusion detection will be best implemented on smart applications layer to attain reliability and efficiency. Intrusion detection, authentication, and privacy preserving authentication is more applicable to co-ordination layer. For the artificial intelligence layer intrusion detection and privacy preserving authentication is applicable. The perception layer is linked with in-vehicular devices and vehicular nodes thus, applicable to the privacy and privacy preserving authentication in relation to CC-V layered architecture.

Table 5. The Summary of related literatures on security

Protocols	Contribution	Architectures	Techniques	Implementation	Remarks
TIaaS [45]	Location privacy scheme	VuC	location-based encryption	No	Cryptography overhead
TCBI [46]	Incentive mechanism	VCC	Framework design	Custom Simulator using JAVA	System complexity issue
ICDI [47]	Adaptive intrusion detection	VCC	Pseudo-dynamic clustering	NS-2 and SUMO	adaptivity processing overhead
VCC-SSF [48]	Authentication scheme	VuC	Cryptography based design	No	Cryptography overhead
PVCM [49]	zone based revocation system	VCC	Algorithm development	No	Complexity analysis issue
CPAS [50]	Delay reduction scheme	VCC	Signature based framework	Matlab	V2V communication not implemented
DPK-LSV [51]	Dual registration detection	VCC	Privacy preserving detection	Custom simulator	Privacy level not defined
PASS [52]	Pseudonymous authentication scheme	VCC	Mathematical framework design	NGSIM project tool	Only highway scenario was considered

Table 6. A comparative assessment on security

Protocol	Techniques			Architectures			IM
	CM	CF	EN	VuC	VCC	HVC	
TIaaS [45]	√			√			
TCBI [46]		√					
ICDI [47]		√			√		√
VCC-SSF [48]		√		√			
PVCM [49]		√		√			
CPAS [50]	√	√			√		√
DPK-LSV [51]	√	√			√		√
PASS [52]	√	√			√		√

CM=Conceptual Model, CF= Complete Framework, EN=Encryption, IM=Implementation. √=Yes and ×=No.

4.4 Applications

CC-V applications are much more essential for realization of operational and effective vehicular ad hoc network communication based on cloud computing [53]. CC-V applications can be divided into three categories, safety, efficiency and infotainment. Safety application are created to enhance vehicle's behavior awareness, so as to eradicate or reduce vehicle crashes via V2V communication. Its applications include control loss warning, emergency electronic brake lights, blind spot/lane change warning etc. V2I communication applications include, oversize vehicle warning, railroad crossing warning, curve speed warning, etc. Vehicle-

to-Pedestrian (V2P) communication include transit pedestrian indication. Some other applications in these categories are listed in Fig. 16.

The major CC-V applications including safety, efficiency and infotainment can be improved on, if the CC-V layered architecture is critically analyzed and incorporated with the application models. Safety applications are most suitable at the smart applications, artificial intelligence and perception layer in terms of functions and protocols. The efficiency applications is best linked to smart applications and perception layer of the layered CC-V. Infotainment can be represented at smart applications, artificial intelligence and perception layer of the CC-V layered architecture.
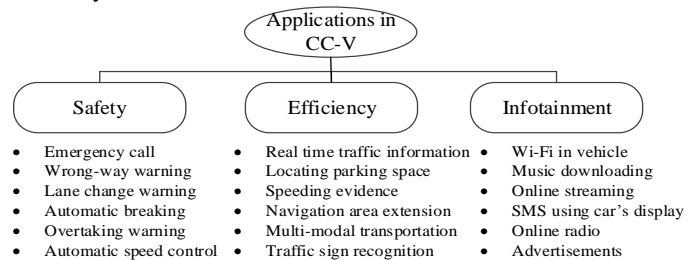

Figure 16. The Applications of CC-V

In a generic term, safety application includes warning and support advisories, and infrastructure and vehicle controls [54].

The efficiency applications provide information on vehicles' and drivers' condition for passenger's comfort, health. The applications monitors both car and driver's performance during journey [55]. Safety applications can be best implemented by considering the functions and its protocols under smart applications, artificial intelligence and perception layers of the CC-V layered architecture.

4.4.1 Safety

Transportation and communication plays a critical role in disaster response and management in order to combat or reduce loss of life and property [56]. An Emergency Disaster Response System (EDRS) and model have been introduced. ERDS system consists of the three main layers as shown in Fig. 17. The layers include infrastructure as a service, intelligence and system interface layer. Infrastructure as a service layer consist of base platform and environment intelligent emergency response system. Intelligent layer provides computational model, and algorithms. The system interface layer acquires data from gateways such as internet, roadside masts, mobile smart phones, and social networks. Lighthill-Whitham-Richards (LWR) model has been adopted for modeling the disaster system. Its effectiveness has been demonstrated in terms of improved disaster evacuation characteristics. Security issues related to the architecture has not been discussed. The result of the findings demonstrate that the functions considered are closely related under smart applications and co-ordination layer of the CC-V layered architecture. The CC-V elements are suitable for emergency disaster response system, since it requires computation, connection and vehicular node for its communication.

A Wireless Access Technology for Vehicular network Safety Applications (WATVSA) has been suggested to address issue of non-reliable broadcast of safety messages, in order to realize standard road safety applications [57]. The adopted wireless technologies includes time division multiple access called Vehicle MAC (VeMAC), latest cellular network standards, and IEEE 802.11p standard. In addition, performance of VeMAC protocol has been compared with that of IEEE 802.11p standard, through simulation considering both urban and highway scenarios. It considers traffic problems caused by emergency parking of vehicles in highway scenarios. Authors claimed that VeMAC has better potentials compared with IEEE 802.11p in terms of broadcasting of safety messages in VANETs. The functions and its protocols under smart applications and c-ordination layer of the CC-V layered architecture is suitable for implementation of the WATVSA applications system. The fundamental component of the applications system including WAVE technology and vehicular node are related to the proposed CC-V elements. However, the optimal values of VeMAC parameters such as, number of time slots per frame, and slot duration are not considered.

Segata and Renato [58] presented an Automatic Emergency Braking with realistic Analysis of Car Dynamics (AEB-ACD), and network performance as one of the important application for VANETs safety. The simulation and analysis of driver behavior awareness have been conducted. Emergency braking application has been simulated, by embedding mobility, cars' dynamic and driver behavior models in to the network simulator. Furthermore, a simpler message aggregation mechanism has been presented to enhance message re-propagation during peak load. The complete system permits capturing the interactions of the communications with vehicle's automated break mechanism and driver's behavior.

The system yields detailed information on the communication level during experimentation as claimed by authors. However, there is a need for refinement of communication channel model, and development of the vehicular dynamics models. The car dynamics and network analysis can be linked to the CC-V elements and archive better performance. It represents the basic components of AEB-ACD including road side infrastructure, vehicle node and cloud computation.
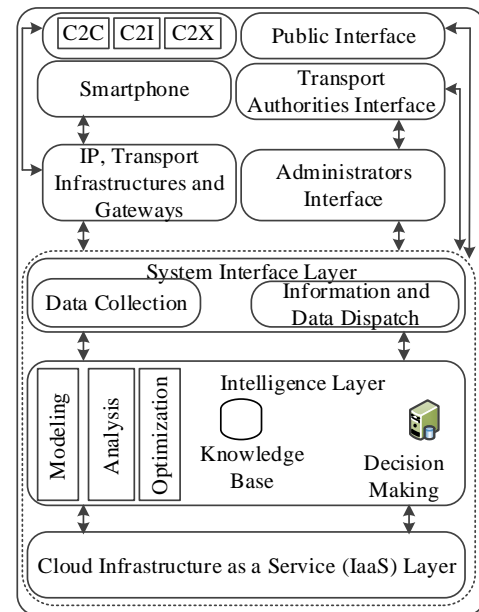

Figure 17. The emergency response application design

In [59], an analysis of information dissemination in vehicular ad-hoc networks with application has been presented. The analysis considers Cooperative Vehicle Safety Systems (CVSSs) to demonstrate functionalities and viability of the systems. Thus, analysis of effect on different communication ranges and rates have been conducted. The novel models that measure network performance in terms of its ability to broadcast tracking information are presented. The study demonstrate that hidden nodes affects VANETs communication. The channel occupancy or busy ratio can be used as feedback measure that quantifies the success of information broadcasted. Consequently, these outcome are used to develop feedback control system for transmission range adaptation. The findings can be closely related to the functions and its protocols considered under smart application and co-ordination layer of the CC-V layered architecture. The major constituent elements of CVSSs related to the CC-V elements are including DSRC network and vehicular node. However, effects of some parameters such as contention window size on information dissemination rate has not been derived.

4.4.2 Efficiency

A Secured Incentive based Architecture for Vehicular (SIAV) cloud has been suggested to address the issues of underutilization of computational, communication and storage

capabilities of vehicles because of non-participation in vehicular cloud [60]. Summary of SIAV is shown in Fig. 18. Two design architecture approaches including system model and secure token reward system have been developed for encouraging the vehicles to participate in computation, and sharing of information. Major components of system model include service provider manager, reward token system, revocation authority, trusted authority, road side unit and on-board units. Secure token reward system has three major phases, namely, searching resources, requesting reward tokens, and using the token for cloud services. The efficiency of the system model has not been evaluated. Efficiency applications can be optimally achieved by considering functions under smart applications and artificial intelligence of the CC-V layered architecture. The proposed CC-V elements can be closely related to computation, vehicular nodes and RSUs.
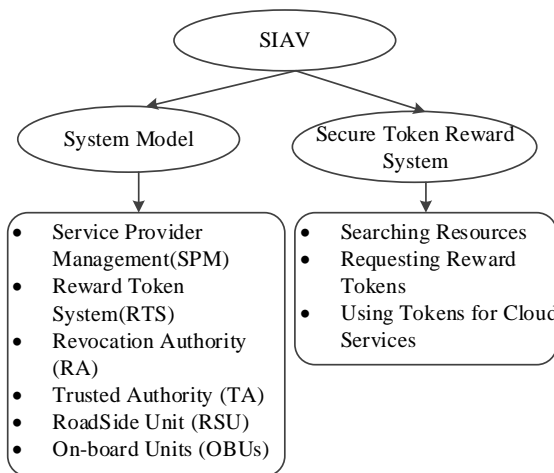

Figure 18. The System Model and Secure Token Reward System

Singh et al. [61] suggested a Secure and reliable Cloud networks for Smart Transportation (SCST) services for accident prevention, monitoring and controlling system [58]. A smart transportation system, and security issues related to the transportation system have been discussed. Smart transportation system have four functional layers including application layer, support layer, network layer and perceptual layer (see Fig. 19). Application layer represents various user applications. Support layer covers the cloud services, network layer entails the Internet for connection. And perceptual layer is the client layer. An algorithm for vehicle detouring procedure in smart transportation system has been developed. The algorithm has been used to solve cloud computing down-time routing problem. The functions of smart transportation system includes preventing accident, finding destination and transfer of accident information to the vehicles using cloud. Implementation of vehicle detouring has not been conducted. The investigation and implementation can be considered to be close to the functions under smart application and perception layer of the CC-V layered architecture. CC-V elements can be linked to the major constituent of the smart transportation services for accident and emergency prevention, controlling and monitoring.

A Real Time services concept for future Cloud computing enabled Vehicle (RTCV) networks has been suggested to ensure real time performance as well as to improve accuracy and comfort degree for drivers [62]. A cloud computing system, real time vehicular cloud services and context classifications have been presented. Vehicular cloud system is partitioned into three tiers including device, communication, and service levels (see Fig. 20). The real time vehicular cloud services are introduced as road traffic and healthcare monitoring, and other customized services. The context information is classified into low and high level context. In another point of view, it can be classified into driver, car and road traffic contexts. The can be related
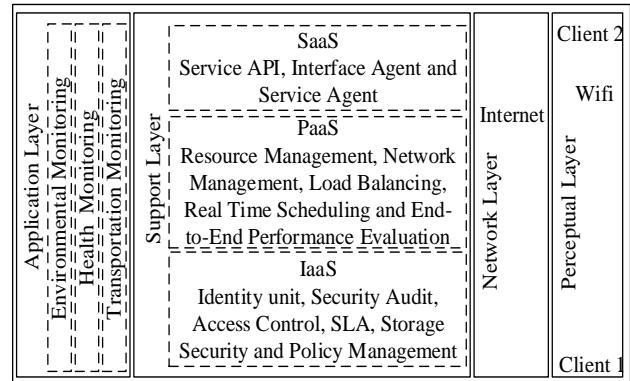

Figure19. The Cloud computing Module for STS system.

4.4.3 Infotainment

In [63], Cloud based Intelligent Transport System (CITS) has been suggested to address increasing transportation problem with the help of infotainment applications. A system for multi-layered vehicular data cloud has been presented. The system employs cloud computing and Internet of Thinks (IoT) technologies. The system has three modules including intelligent parking cloud service, communication from VANETs to cloud, and vehicular data mining cloud. Intelligent parking cloud module handles the decision process of selecting an available parking space for vehicles, and the mobile device with android application service for communication with the cloud. The system has higher interdependence between layers, which might degrade performance of the system. The CITS is closely related to the functions under smart applications, artificial intelligence and perception layer of the CC-V layered architecture. The component which serve as elements of CITS are also applicable for the elements of CC-V and CC-V layered architecture.

Multimedia services have become one of the major research area of interest in both cloud computing and VANETs because of its relevance in both infotainment and safety. Thus, a Multimedia Services in Cloud-based Vehicular Networks (MSCVN) has been employed to integrate cloud computing and storage with vehicles, in order to increase accessibility to multimedia services [64]. Different systems including LTE system for network access, and multimedia cloud computing system have been suggested. Three layered cloud-based vehicular network model, which includes cluster layer, physical layer and perception layer has also been presented. A dynamic road monitoring system has been discussed. In video up-linking scenario, the MSCVN performs closer to the optimum when compared with two well-known schedulers including maximum largest weighted delay first, and exponential. However, delay

in connectivity might arise due to the large audio and video files that need to be transmitted.

Infotainment applications is best represented by considering the CC-V layered architectures' functions and protocols in relation to smart applications, artificial intelligence and perception layers.
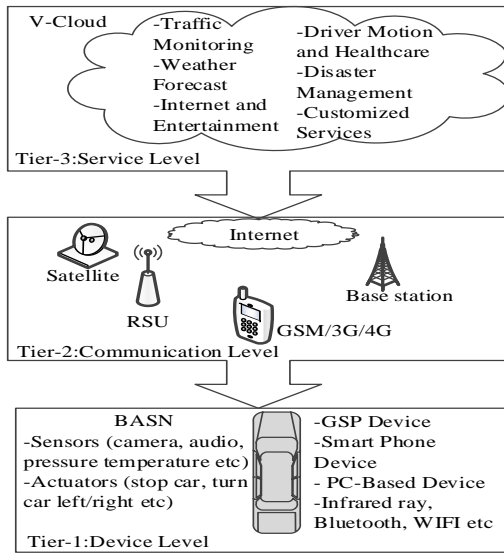

Figure 20. The Three Ties System for Vehicle Cloud

4.4.4 Comparative Discussion on Applications

The aforementioned literature review on application based developments in CC-V is summarized in Table 7. The summary considers the parameters including contribution as service, type of systems suitable for the application, the technique followed in application development, implementation detail of the application and remarks as strength and weaknesses of the application. The contribution highlights the signification of the service provided by the application. The architecture tells the suitability of the application in the cloud based vehicular communication categories including VuC, VCC, and HVC. The techniques are the development methods followed in application. The implementation shows the process and metric for quality attestation regarding the services of the application. The critical remarks are also made in terms of limitations of the application. A comparative analysis is also presented in Table 8. The comparative analysis is based on three parameters including application design technique, suitable system and implementation performed. The application design technique is defined using the basic concept of the application, overall framework, and algorithm of the application operations. The application system is defined using the suitability in the cloud environment for vehicular communications including VuC, VCC, and HVC. The summary and comparative analysis of the application based developments in CC-V suggest that MSCVN [64] is more practical application concept with greater user friendly services. The implementation plan of MSCVN is widely acceptable in CC-V environments. The application model more scalable due to the plugin based service concepts. The CC-V applications can be enhanced in terms of the representations, functions and protocols of the four layers of the aforementioned CC-V layered architecture. The proposed basic elements of CC-V are closely related to the MSCVN elements.

5. FUTURE RESEARCH CHALLENGES

The CC-V is a new paradigm that combines the idea of cloud computing and VANETs. Many research issues need to be addressed for realizing CC-V. These research issues are discussed below:

I. Architecture Design: Due to the fact that CC-V is still a new area of research, there is no generalized standard architecture for this new idea. Although many initial architectures for CC-V have been suggested, yet standard architectures with implementation details are unavailable [25-31]. Therefore, the issue need thorough exploration.

Table 7. The Summary of related literatures on applications

Protocols	Contribution	Architectures	Techniques	Implementation	Remarks
EDRS [56]	Disaster management system	VuC	System design	Mathematical tool	Security issues of the system
WATVSA [57]	reliable broadcasting of safety	VCC	Time division multiple access	NS-2 and VISSIM	Time slots per frame not considered
AEB-ACD [58]	automatic break system	VCC	Algorithms design	NS-3	Refinement of communication channel issue
CVSSs [59]	cooperative vehicle safety framework	VCC	Markov model	OPNET and SHIFT (IDR)	Contention window size issue
SIAV [60]	Incentive based security	VCC	System level design	No	practically not tested
SCST [61]	Vehicle monitoring system	VuC	Algorithm design	No	Distributed monitoring issue
RTCV [62]	Real time safety services	VuC	On demand approach	No	Time constraint issue
CITS [63]	Architecture for safety application	VuC	Framework design	No	multi-layered architecture issue
MSCVN [64]	Multimedia content classification	HVC	Taxonomy based investigation	NS-2	Standard mobility model issue

Table 8 A comparative assessment on applications

Protocol	Techniques			Architectures			IM
	CM	CF	AL	VuC	VCC	HVC	
EDRS [56]	✓	✓		✓			
WATVSA [57]		✓			✓		✓
AEB-ACD [58]	✓	✓	✓		✓		✓
CVSSs [59]	✓	✓			✓		✓
SIAV [60]	✓	✓			✓		
SCST [61]		✓	✓	✓			
RTCV [62]	✓	✓		✓			
CITS [63]		✓		✓			
MSCVN [64]		✓				✓	✓

CM=Conceptual Model, CF= Complete Framework, AL=Algorithm, IM=Implementation. ✓=Yes

II. Data Dissemination: Efficient data dissemination in CC-V is a challenging issue, due to the high dynamicity of vehicles in changing their positions. The design, and how to transmit data in CC-V need to be critically addressed. Even though some work has been done in [32-44] by suggesting solutions to handle various type of data dissemination issues using clustering, data-centric and other routing approaches, yet many issues have not covered, such as, location verification, data dissemination and video centric routing. The conventional VANETs routing [69-71] may not be suitable in the case of CC-V due to the connectivity challenges in mobility.

III. Data Offloading: The complex unrefined data need to be offloaded to conventional cloud or to vehicular cloud for processing. After processing, this refined data is accessed by vehicles and other related organizations. However, the issue of how to offload unrefined data and access the refined data in a high mobility vehicular scenario is required to be looked into. Data aggregation and computation are also required since vehicles uses sensors and other on-board devices for collecting information relating to vehicle, environment and traffic. Hence, the issue of data aggregation and computation are attached clearly, both at vehicle and cloud level. The data need to be aggregated and refined for users.

IV. Application Design and Deployment: Some potential VANETs applications are yet to be designed or deployed at vehicles for efficient usage, such as, Picture and Video Coverage as a Services (PVCaaS) in CC-V. PVCaaS is a service whereby vehicles on the road take pictures, and video covering of their surroundings. The picture and video are automatically offloaded to the cloud for storage and analysis. This services is useful for road safety and security organization. Some of the recent works by [56-64] tackle some application design for incentive-based, disaster management, highway traffic control [72, 73], and multimedia applications.

V. Standardization and Interoperability: The vehicles have heterogeneous devices, such as, sensors, GPS and smartphones. How to make the varied devices to work together efficiently is highly required for data gathering. Standardization is also required for these on-board devices, by looking into compatibility, quality, and implementation of guidelines, interoperability and repeatability of on-board vehicle equipment and software.

VI. Security and Privacy: Security and privacy are also the major challenges in CC-V, because the participating users are always mindful of their privacy and whereabouts at any given time. Also, since vehicles rely on information from the cloud or other vehicle for their navigations, this might cause serious havoc, if there is information distortion by an intruder, it can leads to waste of time, fuel or even loss of life. Several authors [45-52] have made attempt to see how these issues including intrusion detection, authentication and location privacy could be handled. But the reality is that, extensive security related research work need to be done considering both security, privacy, authentication and their efficiency in CC-V.

VII. Delay in Cloud-Client Communication: It is one of the fundamental issue in any cloud based service due to the dynamic network environment and the consideration of cloud infrastructure in high mobile vehicular environment. The sparse distribution of vehicles and the dynamic nature of density of vehicles in the network environment are unavoidable. CC-V requires real-time communication decision in safety applications which is quite challenging considering the delay issue in network access [65-68].

VIII. Autonomous Driving: It is one aspect of ITS which requires artificial intelligence, learning capabilities and storage, for making computational decision on possible route for achieving fast and safe navigation [74, 75]. Cloud computing need to be applied for computation of intelligent data and subsequently, for analysis, which should be accessed by Autonomous vehicle.

IX. Learning-based Data Storage: it is another aspect of ITS which is required in order to achieve distributed ITS. It needs some initial storage of information in VANETs without any provision for device setup [76, 77]. The device setup could be RSU or external access point. Hence, there is need for a robust strengthening learning-based, dynamic and adaptive data storage techniques for VANETs in order to achieve distributive ITS.

6. CONCLUSION

We have reviewed related work and put forth a framework in vehicular communication for CC-V. The framework suffices from the merging of cloud computing, pervasive sensing, improved network mobility and in-build vehicle resources. The large volume of underutilized on-board vehicle resources, such as computing power, Internet and storage could be utilize by various clients Internet, in relation to the conventional cloud resources. Numerous of these resources can provide support for handling traffic incident. CC-V can generate income, enhance security and safety. CC-V can also help to minimize the losses in different types of emergency incidences including fire outbreak, flood or accidents.

In this work, layered architecture for the CC-V is presented. Three elements of CC-V including vehicle, computation and connection are identified, and their relations are discussed in the aspect of CC-V. Several application scenarios, security and privacy, and formation of CC-V has been identified and discussed. We present a taxonomy for CC-V and explored related literature based on the taxonomy. We have also identified open research issues and challenges with regard to CC-V.

However, a number of issues are still not been thoroughly explored by researchers, which include data dissemination to cloud, data offloading, data centric routing, intermittent connection, vehicular cloud networking, VANETs application and deployment, security and privacy-aware data sharing. In conclusion, CC-V could not be fully implemented, except if governments, and automobile industries would come together to utilize the benefit of the framework of CC-V. Thus CC-V could be the next paradigm shift that offers feasible and technologically viable, and smart solutions for traffic issues with economical gains.

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REFERENCES

1. A. K. A. Abdalla and A. S. K. Pathan, "On protecting data storage in mobile cloud computing paradigm." IETE Technical Review, Vol. 31, no. 1, pp. 82_91, Jan. 2014.

2. W. He, G. Yan and L. D. Xu, "Developing vehicular data cloud services in the IoT environment," IEEE Trans. Industrial Informatics, Vol. 10, no. 2, pp. 1587_1595, May. 2014.

3. J. M. De Fuentes, L. González-Manzano, A. I. González-Tablas and J. Blasco, "Security models in Vehicular ad-hoc networks: a survey." IETE Technical Review, Vol. 31, no. 1, pp. 47_64, Jan. 2014

4. H. Zhang, Q. Zhang and X. Du, "Toward Vehicle-Assisted Cloud Computing for Smartphones." IEEE Trans. Vehicular Technology, Vol. 64, no. 12, pp.5610_5618, Dec. 2015.

5. S. Olariu, T. Hristov and G. Yan, "The next paradigm shift: from vehicular networks to vehicular clouds." Cutting Edge Directions. Mobile Ad Hoc Networking, Second Edition, pp. 645_700, 2013

6. M. Gerla, "Vehicular cloud computing." IEEE the 11th Annual Mediterranean. Ad Hoc Networking Workshop (Med-Hoc-Net), pp. 152_155, Jun. 2012.

7. J. K. Lee, Y. S. Jeong and J. H. Park, "s-ITSF: a service based intelligent transportation system framework for smart accident management." Human-centric Computing and Information Sciences, Vol. 5, no. 1, pp.1, Dec. 2015.

8. K. S. Nesamani, L. Chu, M. G. McNally and R. Jayakrishnan, "Estimation of vehicular emissions by capturing traffic variations."Atmospheric Environment, Vol. 41, no. 14, pp. 2996_3008, May. 2007.

9. A. Ghose, P. Biswas, C. Bhaumik, M. Sharma, A. Pal and A. Jha, "Road condition monitoring and alert application: Using in-vehicle Smartphone as Internet-connected sensor." IEEE International Conference. Pervasive Computing and Communications Workshops (PERCOM Workshops), pp. 489_491, Mar. 2012.

10. N. N. Qadri, M. Fleury, M. Altaf and M. Ghanbari, "Multi-source video streaming in a wireless vehicular ad hoc network." IET. Communications, Vol. 4, no. 11, pp. 1300_1311, Jul. 2010

11. M. Hemalatha, S. Nanthini, D. Dhivya and A. Vaishnavi, "Intelligent parking system using vehicular data cloud services." IEEE International Conference. Innovations in Information Embedded and Communication Systems (ICIIECS), pp. 1_5, Mar. 2015.

12. F. Dressler, P. Handle and C. Sommer, "Towards a vehicular cloud-using parked vehicles as a temporary network and storage infrastructure." ACM international workshop. Proceedings of the 2014 on Wireless and mobile technologies for smart cities, pp. 11_18, Aug. 2014.

13. R. Hussain and H. Oh, "Cooperation-Aware VANET Clouds: Providing Secure Cloud Services to Vehicular Ad Hoc Networks." JIPS Vol. 10, no. 1, pp. 103_118, Mar. 2014.

14. M. Whaiduzzaman, M. Sookhak, A. Gani, and R. Buyya, "A survey on vehicular cloud computing." Journal of Network and Computer Applications, vol.40, pp.325-344, 2014.

15. IEEE 802.11p published standard, "Amendment 6: Wireless Access in Vehicular Environments (WAVE)", 2010. Avialable:http://standards.ieee.org/getieee802/download/802.11 p-2010.pdf

16. IEEE Working Group for Wireless Standard, "IEEE 802.11TM Wireless Local Area Networks", Available: http://www.ieee802.org/11/.

17. IEEE 802.16 based standards, "WiMax Forum-Technology", Available: http://www.wimaxforum.org/.

18. C. Cox, "An introduction to LTE: LTE, LTE-advanced, SAE and 4G mobile communications", 1st ed., John Wiley & Sons, UK, 2012.

19. U.S. Department of Transportation, "IEEE 1609 - Family of Standards for Wireless Access in Vehicular Environments (WAVE)", 2013. Available: https://www.standards.its.dot.gov/Factsheets/Factsheet/80.

20. B. Richard, B. Roberto, "European ITS Communication Architecture: Overall Framework-Proof of Concept Implementation", Deliverable 31, COMeSafety Project, 2009.

21. R. Khan, S. U. Khan, R. Zaheer, and S. Khan, "Future internet: the internet of things architecture, possible applications and key challenges", in proceedings of the International Conference on Frontiers of Information Technology (FIT), IEEE, pp. 257-260. Islamabad Pakistan, 2012.

22. Z. Yang, Y. Peng, Y. Yue, X. Wang, Y. Yang, and W. Liu, "Study and application on the architecture and key technologies for IOT", In Proceedings of the International Conference on Multimedia Technology (ICMT), IEEE, pp. 747-751, Hangzhou, China, 2011.

23. O. Brickley, M. Koubek, S. Rea, and D. Pesch, "A network centric simulation environment for CALM-based cooperative vehicular systems", In Proceedings of the International ICST Conference on Simulation Tools and Techniques ICST, pp. 70-75, Brussels, Belgium, 2010.

24. R. Baldessari, B Bödekker, M. Deegener, A. Festag, W. Franz, C. C. Kellum, T. Kosch, A. Kovacs, M. Lenardi, C. Menig, and T. Peichl, T., "Car-2-car communication consortium-manifesto", 2007. Available: https://www.car-2-car.org/index.php?id=31

25. R. Hussain, J. Son, H. Eun, S. Kim and H. Oh, "Rethinking vehicular communications: Merging VANET with cloud computing." IEEE 4th International Conference. Cloud Computing Technology and Science (CloudCom), pp. 606_609, Dec. 2012.

26. R. Hussain, Z. Rezaeifar and H. Oh, "A paradigm shift from vehicular ad hoc networks to VANET-based clouds." Wireless Personal Communications Vol. 83, no. 2, pp. 1131_1158. Jul. 2015.

27. S. Olariu, I. Khalil and M. Abuelela, "Taking VANET to the clouds." International Journal of Pervasive Computing and Communications Vol. 7, no. 1, pp. 7_21. Apr. 2011.

28. S. Bitam, A. Mellouk and S. Zeadally, "VANET-cloud: a generic cloud computing model for vehicular Ad Hoc networks." IEEE Wireless Communications, Vol. 22, no. 1, pp. 96_102, Feb.2015.

29. H. Yan, J. Wan, Y. Wang, Z. Wang and Z. Song, "Vehicular cyber-physical systems with mobile cloud computing support." Springer International Publishing. Cloud Computing, pp. 27_35, Oct. 2013.

30. H. Yao, C. Bai, D. Zeng, Q. Liang and Y. Fan, "Migrate or not? Exploring virtual machine migration in roadside cloudlet-based vehicular cloud." Practice and Experience. Concurrency and Computation Vol. 27, no. 18, pp. 5780_5792, Dec. 2015.

31. E. Lee, E. K. Lee, M. Gerla and S. Y. Oh, "Vehicular cloud networking: architecture and design principles." IEEE Communications Magazine, Vol. 52, no. 2, pp. 148_155, Feb. 2014.

32. Y. Chen, M. Fang, S. Shi, W. Guo and X. Zheng, "Distributed multi-hop clustering algorithm for VANETs based on neighborhood follow." EURASIP Journal on Wireless Communications and Networking, no. 1, pp. 1_12, Dec. 2015.

33. H. R. Arkian, R. E. Atani, A. Diyanat and A. Pourkhalili, "A cluster-based vehicular cloud architecture with learning-based resource management." The Journal of Supercomputing Vol. 71, no. 4, pp. 1401_1426, Apr. 2015.

34. N. Kumar, R. S. Bali, R. Iqbal, N. Chilamkurti and S. Rho, "Optimized clustering for data dissemination using stochastic coalition game in vehicular cyber-physical systems." The Journal of Supercomputing Vol. 71, no. 9, pp. 3258_3287, Sep.2015.

35. M. Ikeda, T. Honda and L. Barolli, "Performance of optimized link state routing protocol for video streaming application in vehicular ad-hoc networks cloud computing." Practice and Experience. Concurrency and Computation, Vol. 27, no. 8, pp. 2054_2063, Jun. 2015.

36. N. Kumar, J. J. Rodrigues, J. Lloret and A. Dua, "Replication-aware data dissemination for vehicular ad hoc networks using location

determination." Mobile Networks and Applications Vol. 20, no. 2, pp. 251_267, Apr. 2015.

37. M. F Feteiha and H. S. Hassanein, "Enabling cooperative relaying VANET clouds over LTE-A networks." IEEE Trans. Vehicular Technology, Vol. 64, no. 4, pp. 1468_1479, Apr. 2015.

38. M. U. Farooq, M. Pasha and K. U. R. Khan, "A data dissemination model for Cloud enabled VANETs using In-Vehicular resources." IEEE International Conference. Computing for Sustainable Global Development (INDIACom), pp. 458_462, Mar. 2014.

39. S. Bitam and A. Mellouk, "Cloud Computing-Based Message Dissemination Protocol for Vehicular Ad Hoc Networks." Springer International Publishing. Wired/Wireless Internet Communications, pp. 32_45, May. 2015.

40. Y. W. Lin, J. M. Shen and H. C. Weng, "Cloud-supported seamless Internet access in intelligent transportation systems." Wireless personal communications Vol. 72, no. 4, pp. 2081_2106, Oct. 2013.

41. M. Ikeda, T. Honda and L. Barolli, "Performance of optimized link state routing protocol for video streaming application in vehicular ad-hoc networks cloud computing." Practice and Experience. Concurrency and Computation, Vol. 27, no. 8, pp. 2054_2063, Jun. 2015.

42. X. Wang, "IPv6-Based Vehicular Cloud Networking." IEEE Communications Letters, Vol. 19, no. 6, pp. 933_936, Jun.2015.

43. N. Cordeschi, D. Amendola, and E. Baccarelli. "Reliable adaptive resource management for cognitive cloud vehicular networks." Vehicular Technology, IEEE Transactions, Vol. 64, no. 6, pp. 2528_2537, Jun. 2015.

44. K. Zheng, H. Meng, P. Chatzimisios, L. Lei and X. Shen. "An SMDP-Based Resource Allocation in Vehicular Cloud Computing Systems." IEEE Trans. Industrial Electronics, Vol. 62, no. 12, pp. 7920_7928, Dec. 2015.

45. R. Hussain, Z. Rezaeifar, Y. H. Lee and H. Oh. "Secure and privacy-aware traffic information as a service in VANET-based clouds." Pervasive and Mobile Computing, Vol. 24, pp. 194_209, Dec. 2015.

46. J. Zhou, X. Dong, Z. Cao and A. V. Vasilakos, "Secure and privacy preserving protocol for cloud-based vehicular DTNs." IEEE Trans. Information Forensics and Security, Vol. 10, no. 6, pp. 1299_1314, Jun. 2015.

47. N. Kumar, J. P. Singh, R. S. Bali, S. Misra and S. Ullah. "An intelligent clustering scheme for distributed intrusion detection in vehicular cloud computing." Cluster Computing, Vol. 18, no. 3, pp. 1263_1283, Sep. 2015.

48. Kang, Won Min, Jae Dong Lee, Young-Sik Jeong, and Jong Hyuk Park. "VCC-SSF: service-oriented security framework for vehicular cloud computing." Sustainability, Vol. 7, no. 2, pp. 2028_2044, Feb. 2015.

49. I. M. Abumuhfouz, and K. Lim. "Protecting Vehicular Cloud against malicious nodes using zone authorities." IEEE SoutheastCon, pp. 1_2, Apr. 2015.

50. K. A. Shim. "An Efficient Conditional Privacy-Preserving Authentication Scheme for Vehicular Sensor Networks." IEEE Transactions on Vehicular Technology, Vol. 61 no. 4, pp. 1874-1883, May. 2012.

51. R. Lu, X. Lin, X. Liang and X. Shen. "A dynamic privacy-preserving key management scheme for location-based services in vanets." IEEE Transactions on Intelligent Transportation Systems Vol. 13, no. 1, pp. 127-139, Mar. 2012.

52. Y. Sun, R. Lu, X. Lin, X. Shen, and J. Su, "An efficient pseudonymous authentication scheme with strong privacy preservation for vehicular communications." IEEE Transactions on Vehicular Technology Vol. 59, no. 7, pp. 3589-3603, Sep. 2010.

53. Site, ITS Deployment Tracking Web. "US Department of Transportation, ITS Joint Program Office." (2005).

54. J. Yin, T. ElBatt, G. Yeung, B. Ryu, S. Habermas, H. Krishnan, and T. Talty, "Performance evaluation of safety applications over DSRC vehicular ad hoc networks." Proceedings of the 1st ACM international workshop on Vehicular ad hoc networks. ACM, Oct. 2004.

55. H. Hartenstein, "VANET: vehicular applications and inter-networking technologies." Ed. Kenneth Laberteaux. Vol. 1. Chichester: Wiley, Jan. 2010.

56. Z. Alazawi, S. Altowaijri, R. Mehmood and M. B. Abdljabar, "Intelligent disaster management system based on cloud-enabled vehicular networks." IEEE 11th International Conference. ITS Telecommunications (ITST), pp. 361_368, Aug. 2011.

57. H. A. Omar, Hassan, L. Ning and Z. Weihua. "Wireless access technologies for vehicular network safety applications." IEEE Network, to be published.

58. M. Segata and L. C. Renato, "Automatic emergency braking: realistic analysis of car dynamics and network performance." IEEE Transactions on Vehicular Technology Vol. 62, no. 9, pp. 4150-4161, Nov. 2013.

59. Y. P. Fallah, C. L. Huang, R. Sengupta, and H. Krishnan, "Analysis of information dissemination in vehicular ad-hoc networks with application to cooperative vehicle safety systems." IEEE Transactions on Vehicular Technology Vol. 60, no.1 pp. 233-247, Jan. 2011.

60. K. Lim, I. M. Abumuhfouz and D. Manivannan, "Secure Incentive-Based Architecture for Vehicular Cloud." Springer International Publishing. Ad-hoc, Mobile, and Wireless Networks pp. 361_374, Jun. 2015.

61. D. Singh, M. Singh, I. Singh, and H. J. Lee, "Secure and reliable cloud networks for smart transportation services." IEEE 17th International Conference. Advanced Communication Technology (ICACT), pp. 358_362, Jul. 2015.

62. J. Wang, J. Cho, S. Lee and T. Ma. "Real time services for future cloud computing enabled vehicle networks." IEEE International Conference. Wireless Communications and Signal Processing (WCSP), pp. 1_5, Nov. 2011.

63. K. Ashokkumar, B. Sam and R. Arshadprabhu. "Cloud based intelligent transport system." Procedia Computer Science Vol. 50, pp. 58_63, Dec. 2015.

64. M. K. Jia, S. C. Huang, J. N. Hwang and A. V. Vasilakos, "Multimedia services in cloud-based vehicular networks." IEEE Intelligent Transportation Systems Magazine, Vol. 7, no. 3, pp. 62_79, Jul. 2015.

65. Y. Liu, J. Niu, J. Ma, L. Shu, T. Hara, and W. Wang. "The insights of message delivery delay in VANETs with a bidirectional traffic model." Journal of Network and Computer Applications Vol. 36, no. 5, pp. 1287-1294, Sep. 2013.

66. A. Mehmood, H. Song, H. and J. loret, "Multi-agent based framework for secure and reliable communication among open clouds," In Network Protocols and Algorithms Vol. 6, no. 4, pp. 60-76, 2014.

67. K. Shafiee, and C. L. Leung. "Connectivity-aware minimum-delay geographic routing with vehicle tracking in VANETs." Ad Hoc Networks, Vol. 9, no. 2 pp. 131-141, Mar. 2011.

68. J. Li and C. Chunxiao. "Delay-aware transmission range control for VANETs." Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE, pp. 1-6. IEEE, 2010.

69. O. Kaiwartya, S. Kumar, D.K. Lobiyal, A.H. Abdullah, and A.N. Hassan, "Performance improvement in geographic routing for vehicular Ad Hoc networks." Sensors Vol. 14, no. 12, pp. 22342-22371. 2014.

70. W. Ren, "uLeepp: An Ultra-Lightweight Energy-Efficient and Privacy-Protected Scheme for Pervasive and Mobile WBSN-Cloud Communications," Adhoc & Sensor Wireless Networks, 27, pp.173-195, 2015.

71. C. Wu, S. Ohzahata, Y. Ji, and T. Kato, "How to Utilize Inter-flow Network Coding in VANETs: A Backbone Based Approach," IEEE Transactions on Intelligent Transportation Systems, vol.17, no.8, pp. 2223-2237, 2016.

72. O. Kaiwartya, and S. Kumar. "Guaranteed Geocast Routing Protocol for Vehicular Adhoc Networks in Highway Traffic Environment." Wireless Personal Communications Vol. 83, no.4, pp. 2657-2682. Aug. 2015.

73. R. Chang, and C. Chuang, "A service-oriented cloud computing network management architecture for wireless sensor networks," Ad-hoc & sensor wireless networks, 22(1-2), pp.65-90, 2014.

74. M. Gerla, E. K. Lee, G. Pau and U. Lee. "Internet of vehicles: From intelligent grid to autonomous cars and vehicular clouds." Internet of Things (WF-IoT), 2014 IEEE World Forum on. IEEE, (pp. 241-246) Mar. 2014.

75. A. Briones, R. de Pozuelo, J. Navarro, and A. Zaballos, "Resource Allocation on a Hybrid Cloud for Smart Grids," Network Protocols and Algorithms, 8(1), pp.7-25, 2016.

76. C. Wu, T. Yoshinaga, Y. Ji, T. Murase, and Y. Zhang, ``Reinforcement Learning-based Data Storage Scheme in Vehicular Ad Hoc Networks,'' Proc. IEEE ICC, pp.1-6, 2016.

77. C. Yang, J. Ma, and J. Ren, "Provable Ownership of Encrypted Files in De-Duplication Cloud Storage," Ad Hoc & Sensor Wireless Networks, 26(1-4), pp.43-72, 2015.

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