CONNECTED VEHICLES CLOUD COMPUTING (CVCC): APPLICATIONS, CHALLENGES, AND COMMUNICATION MODELS

Anthony Winchester[1]

[1]Department of Applied Computer Science,
Birmingham-Southern College, Birmingham, Alabama 35254

Correspondence: Anthony Winchester (agwinche@bsc.edu)

ABSTRACT

If the dream of autonomous vehicles is to be realized, sophisticated computational and communication frameworks must be developed. While it is immediately apparent that such a system must be accurate, it may be less obvious that it must also be very efficient. In this paper, an autonomous vehicle system framework is presented. A case study, prepared to demonstrate the system, is detailed.

Connected Vehicular Cloud Computing (CVCC) is a mobile computing model that substitutes the stationary nodes of traditional cloud computing for mobile nodes attached to vehicles. CVCC architecture involves a one-to-one communication with a Cloud platform. This situation is already efficient for inter-vehicle operations. However, for inter-vehicle events, such a communication system can result in unacceptable delays in response time. To deal with this fact, a parallel system has been proposed.

One such system is the Vehicular Ad-Hoc Network (VANET). The VANET employs sensors and transmitters on vehicles to convey traffic information to stationary roadside units. The roadside units rely on Cloud resources to process the incoming information, and then convey results to affected vehicles within range.

It is proposed that CVCC and VANET could be combined to produce real-time monitoring and smart adjustments for autonomous vehicles in traffic conditions. The data collected by such a system make possible new artifacts and processes for traffic management and public safety. Several proposals are discussed in this paper.

The limitations of the CVCC/VANET system are set out, as well as the limitations of competing systems. Finally, the Least Action Principle (LAP) is introduced. The LAP is proposed for use as a method to simplify the complex communication network required for the safe regulation of autonomous vehicle traffic.

Keywords: cloud computing, OSM, SUMO, vehicular communications

LIST OF ABBREVIATIONS

5G	Fifth Generation
ABG	Alpha Beta Gamma
AVC	Autonomous Vehicular Clouds
CC	Cloud Computing
CVIM	Common Vehicle Information Model
CVCC	Connected Vehicles Cloud Computing
ELP	Electronic License Plate
GPS	Global Positioning System
HOV	High Occupancy Vehicle
I	Infrastructure
IAP	Infrastructure Access Points
IaaS	Infrastructure as a Service
IEEE	Inst. of Electrical & Electronic Engineering
LOS	Line Of Sight
LTE	Long Term Evolution
MCC	Mobile Cloud Computing
NIST	National Inst. of Standards and Technology
OBU	OnBoard Unit
OS	Operating System
OSM	Open Street Maps
PaaS	Platform as a Service
PL	Path Loss
RADAR	Radio Detection And Ranging
RSU	Road Side Unit
SaaS	Software as a Service
SNR	Signal to Noise Ratio
SUMO	Simulation of Urban Mobility
UE	User Equipment
V	Vehicle
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VANET	Vehicular Ad-hoc NETwork
VC	Vehicular Cloud

1 INTRODUCTION

Wireless communication is a fast-growing technology to enhance the adaptability and portability of devices. These enhancements permit diverse frameworks in vehicles to satisfy the requirements of drivers and passengers [1]. To help their vehicles compete, car manufacturers offer robust onboard devices, including powerful computers, as well as a variety of sensors, cameras, and wireless transceivers. Most customers need their vehicles to provide seamless extensions of their homes. They need dashboards with entertainment centers, access to the internet, location specific services and online gaming [2]. In today's society, there is a move to connect vehicles to the Internet enabling vehicles to share various types of information. This includes traffic conditions, navigation information, and non-driving related information such as music, videos, driver's feelings or mental status with cars or infrastructure. The current number of cars on the roads is quite high leading to an enormous potential for social-inspired mobility services [3].

Vehicle to vehicle (V2V) communication is primarily focused on giving the vehicle and driver safety alerts. Connected cars technology focuses on vehicle monitoring and location tracking systems. This data is sent to a base locale to be manipulated for multiple uses. Seamless connections could be established with mobile networks to stream unlimited videos to back seats and active safety guides before any accidents happen [4]. Connected vehicular cloud computing (CVCC) and the Vehicular Ad-Hoc Network (VANET) can realize real-time monitoring and smart adjustment of traffic conditions. With the data collected by vehicles and sent to leading cloud computing platforms, there are many opportunities for optimizing traffic systems.

CVCC is a mobile computing model, which extends the stationary nodes of traditional cloud into mobile nodes composed of vehicles [5]. The appearance of CVCC optimizes the performance of VANETs, but also makes its network more complicated [6, 7]. From the one-to-one communication with the cloud platform to the fully connected vehicle network with the cloud platforms, several changes have taken place in the structure of VANETs [8].

1.1 Vehicular Ad-hoc NETworks (VANETs)

VANET architecture consists of vehicles (V), Road Side Unit (RSU) and Infrastructure (I). Communication is done using wireless standards (e.g. IEEE 802.11p). RSU acts like a router and has higher coverage than vehicles. Vehicles are installed with an On Board Unit (OBU) for communication and a Global Positioning System (GPS) for knowing position and for tracking other vehicles. Identification is done using Electronic License Plate (ELP). RAdio Detection And Ranging (RADAR) is also used for knowing other vehicles' positions [9].

In VANETs, the vehicles communicate with each other and/or with the road infrastructure, with a range of 300 to 1000 m. There are two types of VANETs: the no infrastructure VANETs and the infrastructure-based VANETs. With the no infrastructure VANET, also known as Vehicle to Vehicle (V2V) communications, there are many security and privacy problems because no infrastructure is used for authentication and authorization. The infrastructure-based VANET, known as Vehicle to Infrastructure (V2I) communications, can be formed by the road infrastructure, see Figure 1. The infrastructure acts as wireless access points for authentication and authorization processes. The vehicles can use the infrastructure to report events and to exchange information [2], [10].

V2V communication uses multi-hop communication for transmission of data. Inter-vehicle communication consists of two types of communication. The first is producing beacons at regular intervals. The main drawback of this communication type is an increase in message traffic leading to message collisions. The second type is on-demand message generation leading to a reduced number of message collisions [11].

V2I communication uses single-hop communication. It needs a high bandwidth link between the vehicles and the RSUs. The RSU detects the vehicle's speed. A visual alarm could be sent if the vehicle speed is more than the limit [12], [13].

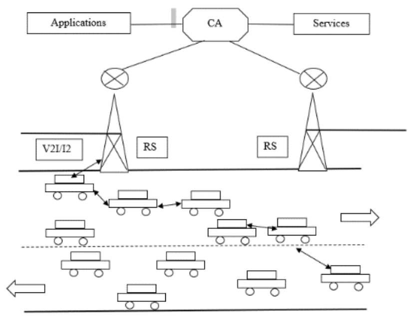

Figure 1. VANET architecture [14].

1.2 Cloud Computing (CC) and Mobile Cloud Computing (MCC)

The National Institute of Standards and Technology (NIST), gives a definition of CC: "Cloud Computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction".

Recently, cloud computing and its applications change the way of thinking about computing and data storage. Cloud users do not have to install special hardware and software. Instead, they can subscribe and use cloud-based hardware and software upon demand. Fees are charged based on service usage. These services can be accessed through Internet browsers, and no expensive client terminals are needed. Service providers can make good use of excess capabilities on the server side by providing services to clients [13].

The Mobile Cloud Computing Forum defines MCC as follows (MCC-forum, 2011): "Mobile Cloud Computing at its simplest refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and mobile computing to not just smartphone users but a much broader range of mobile subscribers".

The architecture for MCC is illustrated in Figure 2. This architecture consists of three layers, the Application layer, the Platform layer and the Infrastructure layer. Each layer gives a specific service for users. They are explained as follows:

Infrastructure layer or Infrastructure as a Service (IaaS): Resources, computing, network, hardware and storage are included in this layer. In the bottom layer of the framework, infrastructure devices and hardware are provided as a service to users to install the operating system (OS) and operate software applications [14].

2. Platform layer or Platform as a Service (PaaS): Mobile operating systems such as Android, iPhone and other OS, as well as database management are included in this layer. Distributing storage, parallel programming and system management tools for cloud computing are done in this layer [15].

3. Application Layer or Software as a Service (SaaS): Analytical, interactive, transaction and browsing facilities are done in this layer.

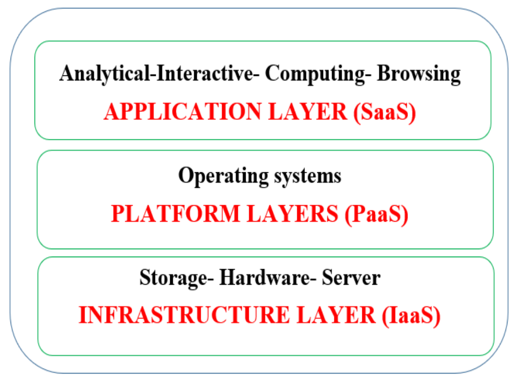

Figure 2. Mobile Cloud Computing Architecture.

2 Applications and Challenges of Connected Vehicles Cloud Computing (CVCC)

Connected vehicles have the potential to transform the way people travel. A safe, interoperable wireless communications network is expected to be created. This network includes cars, buses, trucks, trains, traffic signals, smart phones, and other devices.

Signals shared between the vehicles and with infrastructure access points will generate new data about how, when, and where vehicles travel. This data-rich environment will be the basis for new applications that will make our roads safer, less congested, and more ecofriendly.

In this chapter, applications and challenges of CVCC are presented.

2.1 Applications of CVCC

Vehicular Cloud Computing has many pragmatic applications that can prove beneficial for the 21st century. Safety messages for vehicles, high occupancy vehicle lanes, parking spaces management and law enforcement using cloud technology are among these applications [5]. These applications will be described with more detail in the following paragraphs.

Safety messages for vehicles: There are many vehicular accidents that may be avoided due to network intervention. Cloud networks can synchronize traffic lights after an accident. In a dynamic way, the onboard computers in the vehicles connected to the cloud can coordinate lights to alleviate congestion after a traffic accident. Also, the same model can be used to provide the best routing options to reduce the number of accidents by alleviating traffic. Another related application is obstacle object detection if multiple cars are detected dodging something in the road. The question is “How much better is a sensor coupled with the cloud?” If networked, sensors can detect an object in the road in enough time to make the appropriate adjustments. This can increase safety on the road when there is an obstruction present [8].

High Occupancy Vehicle Lanes: High occupancy vehicle (HOV) lanes helpful in some cities by accommodating vehicles with multiple passengers reducing the number of vehicles on the road during periods of high traffic congestion. However, police officers do not have the technology to determine or enforce time-adjustable restrictions on HOV use.

Also, emergency vehicles such as fire trucks and ambulances that have critical travel have the potential to benefit from cloud technology. Vehicular Clouds (VCs) could dynamically setup HOV lanes by stimulating the flow of traffic and reducing the travel times for HOV lanes. VCs can dynamically provide the solution by collecting data from on board vehicle sensors. This can possibly allow an emergency vehicle to reach a destination more quickly to treat an emergency [11]

Parking Space Management: Finding a convenient parking space in the downtown area of a big city or a university campus or anywhere there are limited available parking spaces can be frustrating. The problem of managing parking availability is wide-spread and a pervasive one, and there several solutions that have been reported. The idea is that by real-time gathering of information about the availability of parking at various locations inside the city, an Autonomous Vehicular Cloud (AVC) consisting of the vehicles that happen to be in a certain neighborhood will be able to maintain real time information about the availability of parking and direct the drivers to the most promising location where parking is currently available. With the use of sensors and real time dynamic cloud technology, parking lots in large cities and on university campuses can give a person information as to the availability of parking spaces [8].

Law Enforcement using Cloud Technology: Law enforcement officers are key in keeping the road safe for commuters. If a police vehicle is present, it can serve as a deterrent for non-law-abiding drivers. Autonomous Vehicular Clouds (AVC) can be utilized as a strategic tool in alerting police of an issue. Collections of vehicles form autonomous vehicular clouds, which can inform police officers to decide the next course of action in approaching a suspect. Autonomous Vehicular Clouds (AVC) are very useful tools in law enforcement to identify aggressive drivers and other violators in conjunction with surveillance cameras and aircraft (drones). This information in turn can be provided to officers for effective use of deploying law officials to an area [11].

Urban Surveillance: Monitoring and surveillance of the environment using video cameras and sensors are increasingly important functions in many urban areas. Modern vehicles are equipped with sensors and cameras as part of the basic package price. Cameras and sensors are sometimes fixed to objects in the environment such as light poles, roof tops, traffic lights, etc. It is possible to sometimes use vehicle’s cameras and sensors as surveillance, this may prevent possible attacks. An example is when a terrorist group is in a certain area planning an assault. To prevent the attack, vehicle cameras and sensors are utilized with the cloud to create a smart environment that can capture questionable behavior. After the video and sensors detect the behavior of interest, this can be given to authorities for investigation. Video is used for forensic investigation; it can be utilized to reconstruct previous activity to deduce a critical event. For example, license plates can be captured on cameras and sensors can trigger other vehicle cameras for more profiling information. The sensors themselves can be used to trigger alarms, call the authorities, and record footage for evidence. The networking of these systems can empower our environment to become automated to serve humanity in a totally new capacity [5].
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2.2 Challenges of CVCC

The CVCC technology faces many challenges, such as security and privacy issues, varying traffic scenarios and global standards.

The varying traffic scenarios: The vehicular clouds must be able to adapt to several traffic scenarios. For example, there could be special events that increase the volume of traffic, or an emergency may arise. Natural disasters may develop in an area, and the vehicular clouds will need to have the capability to adjust. As continuous optimization occurs, more technology will have to be developed to accommodate the premise of developing smart traffic technology.

Global Standards: Currently there are no global standards for vehicular data clouds such as the methods to handle service integration, security, privacy, architecture, and communications.

Security and Privacy: In a world where there are hackers, security will need to be emphasized. Laws and regulation are needed to secure the vehicular data clouds and prevent unauthorized access to individual vehicle data.

The main targets of an attacker include vehicle identification and fingerprinting, collected data stored on board the vehicle, as well as vehicle location including determine a mapping of the user’s frequent paths. Additionally, a hacker may attempt to obtain unauthorized privileges to alter the vehicle operation or redirect where vehicle sensor data is transmitted.

3 Car To Cloud Communication Model

To make a simulation scenario for the CVCC, we need to divide the process into three basic steps. The first step is to model the environment. The second step is to study the communication model. Also, studying the propagation channel model is very important to estimate the received signal parameters. The received signal should be of sufficient power density and suitable BER to give right decisions after processing. The last step is the collected data analysis.

3.1 Environment modeling

The environment model is based on selecting a map to work on. Selecting a real environment to work on is better from the propagation channel modeling point of view. Since propagation channels are in general stochastic random processes, their models are dependent on real environment measurements. Real maps are found in many applications. One of these applications is Open Street Map (OSM). OSM is a community driven project provides an open, free-to-use and highly precise map that includes streets, buildings, traffic lights, speed limits and more. Different traffic states can be considered [16]. Figure 3 shows an example of a OSM map.

To complete the environment model, the locations of the Infrastructure Access Points (IAP) should be known. These IAP locations could be imported from the public databases for telecommunications. *Cellmapper* is one of the available applications to show the locations of the IAPs [17]. Figure 4 shows the IAPs' locations in a part of Birmingham, Alabama as provided by *Cellmapper*.

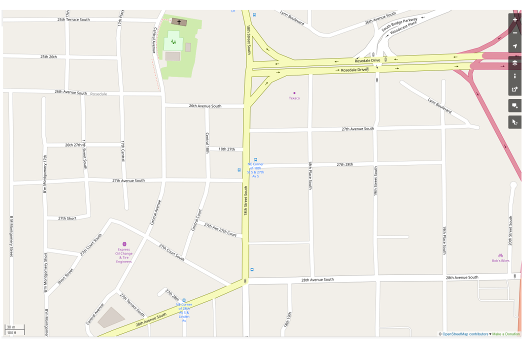

Figure 3. An OSM map of a part of Birmingham, Alabama [16].

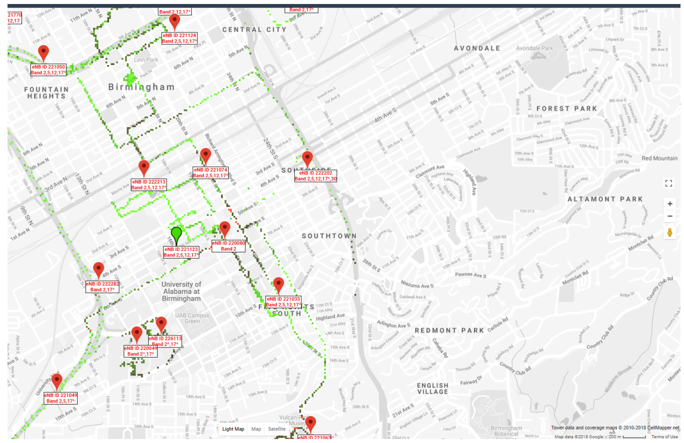

Figure 4. LTE IAPs' locations from Cellmapper. [17].

Realistic mobility could be simulated using open-source software Simulation packages. Simulation of Urban MObility (SUMO) is a good example. SUMO uses the environment road network as input [18].

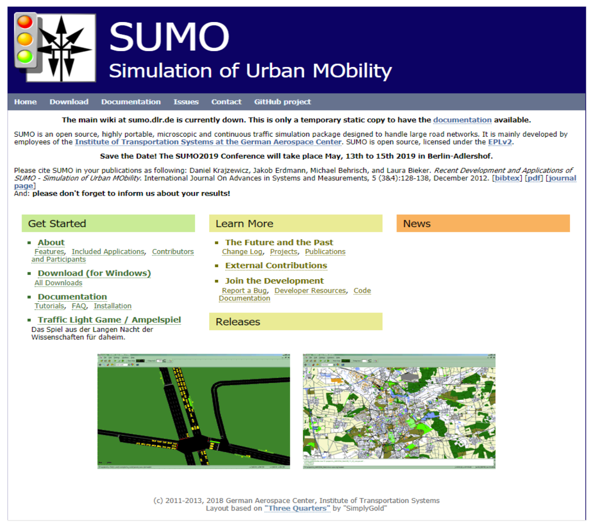

Figure 5. SUMO web site. [19].

3.2 The Communication Model.

In this report, data upload realization from vehicles to cloud is considered to be through LTE. The car to cloud communication is modeled by the communication between LTE user equipment and LTE IAP. The channel model that will support this operation is based on the 3GPP channel model [20]. The line-of-sight LOS probability model considered will be:

$$P(d) = \min\left({}^{d_1}\!/_{d}, 1\right)\left(1 - e^{-d/d_2}\right) + e^{-d/d_2} \qquad (1)$$

, where d is double the distance between UE and IAP in meters, d_1 and d_2 are chosen to fit the environment [21]. This model considers the Urban Microcells. Figure 6 shows the MATLAB calculation of the LOS probability with respect to the distance between UE and IAP for d_1=18 and d_1/d_2=20.

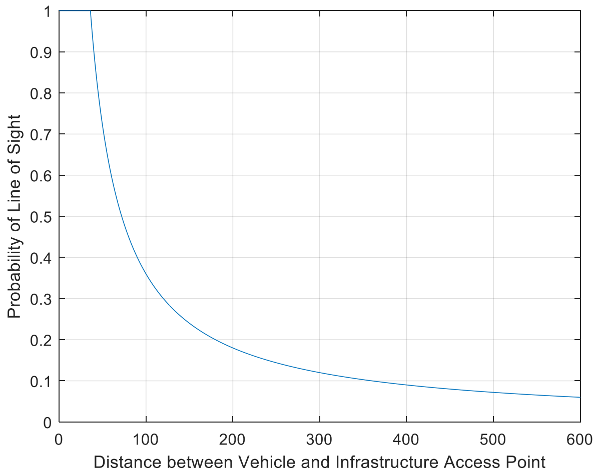

Figure 6. Probability of LOS between UE and IAP

The path loss model considered here is the Alpha- Beta-Gamma (ABG) PL model. This model is the one currently used in the 3GPP 3D model.

$$PL^{ABG}(f,d)[dB] = 10\alpha log_{10}(d) + \beta + 10\gamma log_{10}(f) + X_{\sigma}^{ABG} \quad (2)$$

The definitions and values of the constraints used in this model are listed in Table 1.

The chosen operating frequency is 28GHz. The relation between the PL and the distance between UE and IAP is drawn using MATLAB in figure 7. The multipath components are described by the delays and the directions of departure and arrival. Ray tracing can give good analysis of these components [22].

Table 1 Definitions and selected values of the constraints in Path Loss model.

Constraint	Definition	Selected value
α	Captures how the PL increases as the transmit- receive distance (in meters) increases.	3.48
β	A floating offsetvalue in db.	21.02
γ	Attempts to capture the PL variation over the frequency *f* in GHz.	2.34
$X^{ABG}{}_{\sigma}$	The sf term with standard deviation in db.	7.8

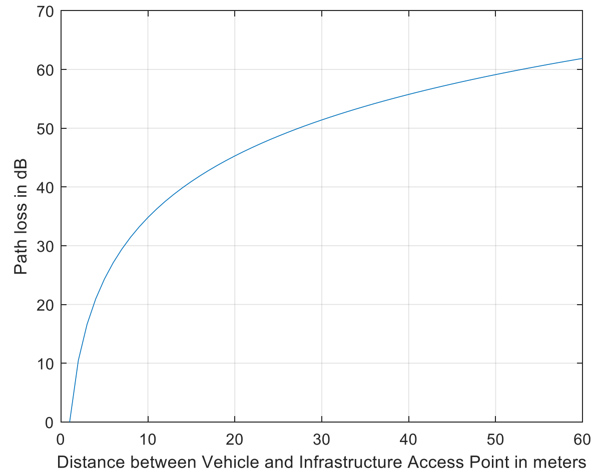

Figure 7. PL in dBs.

The UE is always associated to the nearest IAP providing the best SNR. Data rate used is based upon uplink channel measurements and combines SNR and vehicle speed to derive the available data rates. Figure 8 shows a simulation of different data rates messaging between UE and IAP.

Messages can be transmitted and received between vehicles and the cloud at various periodic rates as shown in Figure 8 using CAN identifier in MATLAB.

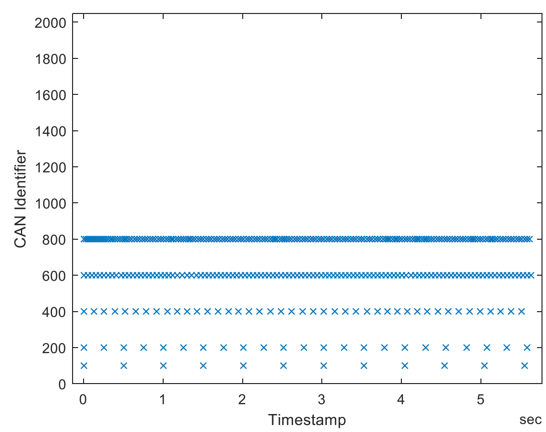

Figure 8. Generating messages at different rates from vehicle to cloud.

3.3 Vehicular data traffic model

The data from the vehicle into cloud is formatted in the Common Vehicle Information Model (CVIM). The data is always aggregated for one second into one CVIM data package and then sent to the cloud. There is always data available, and data is only sent if available data rate is sufficient for the application requirements. More details can be found in [6].

In conclusion, society is headed in the direction of AI and IoT use in technical artifacts that we interact with daily. Vehicles are becoming more inundated with technical methodologies that allow mobile hardware to become more featured with abilities that include safety, convenience, and novelty. In the 21st century we are optimizing the way we utilize our resources for fuel and power which ushers us into using more computing in vehicles, such electric cars which must be regulated by computers. Using the data that commuters collect as we travel can provide is with information that allows us grow in our daily interactions with our devices and each other.

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