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Network Traffic Control System For Vehicular Video Streaming

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Abstract

The vehicle network (VANET) is an essential element of intelligent transport systems, which have become a crucial area of research, thanks to technological changes in recent years. These networks generally consist of fixed entities (RSUs) and mobile entities (vehicles). The main objective is to ensure a reliable level of road safety and a comfortable aspect of traveling. With the evolution of Internet capabilities, vehicles have become more intelligent on the road, where a new range of modern applications has emerged in the form of communication, management and control. These services allow vehicles to communicate and disseminate safety information through messages and videos, also for the comfortable aspect of traveling by using video streaming and other applications. Indeed, these services are hosted on a modern infrastructure designed for communication such as cloud computing. This convergence leads to the appearance of new paradigms linked to vehicles, namely Vehicular Cloud Computing (VCC) and Vehicular Fog Computing (VFC). Despite these advances, the dissemination of messages in most vehicle scenarios remains a major challenge due to packet delays due to the high mobility of vehicles on the road, frequent changes in topology and the high density of vehicles, which lead to road events and frequent packet loss. The aim of this thesis is subscribed in the context of Vehicular Fog Computing (VFC) applications.

Despite the fact that video streaming is the most widely supported and network-sensitive application while driving, we propose a network traffic control system for vehicular video streaming based on the creation of virtual networks. This virtual network is a subset (cluster) of the nodes connecting to each other to achieve efficient routing of information for video streaming packets. This mechanism adapts to the change in topology and the high mobility of the nodes. At the evaluation stage, we simulate the performance of this mechanism using an Omnetpp simulator.

Keywords : VANET (Vehicular adhoc network), video streaming, CC (Cloud Computing), FC (Fog Computing), Quality of Service, Quality of Experience, VFC (Vehicular fog computing).

Résumé

Le réseau de véhicules (VANET) est un élément essentiel des systèmes de transport intelligents, qui sont devenus un domaine de recherche crucial, grâce aux évolutions technologiques de ces dernières années. Ces réseaux sont généralement constitués d'entités fixes (RSU) et d'entités mobiles (véhicules). L'objectif principal est d'assurer un niveau fiable de sécurité routière et un aspect confortable des déplacements. Avec l'évolution des capacités d'Internet, les véhicules sont devenus plus intelligents sur la route, où une nouvelle gamme d'applications modernes a émergé sous la forme de communication, de gestion et de contrôle. Ces services permettent aux véhicules de communiquer et de diffuser des informations de sécurité à travers des messages et des vidéos, également pour l'aspect confortable du voyage en utilisant le streaming vidéo et d'autres applications. En effet, ces services sont hébergés sur une infrastructure moderne conçue pour la communication telle que le cloud computing. Cette convergence a conduit à l’apparition de nouveaux paradigmes liés aux véhicules, à savoir le Vehicular Cloud Computing (VCC) et le Vehicular Fog Computing (VFC). Malgré ces avancées, la diffusion de messages dans la plupart des scénarios de véhicules reste un défi majeur en raison des retards de paquets dus à la grande mobilité des véhicules sur la route, aux changements fréquents de topologie et à la forte densité des véhicules, qui mènent à des accidents de la route et à de fréquentes pertes de paquets. L’objectif de cette thèse est souscrit dans le contexte des applications de Vehicular Fog Computing (VFC).

Malgré le fait que le streaming vidéo soit l’application la plus largement supportée et sensible au réseau pendant la conduite, nous proposons un système de contrôle du trafic réseau pour le streaming vidéo véhiculaire basé sur la création de réseaux virtuels. Ce réseau virtuel est un sous-ensemble (cluster) des nœuds se connectant les uns aux autres pour obtenir un routage efficace des informations pour les paquets de streaming vidéo. Ce mécanisme s’adapte au changement de topologie et à la grande mobilité des nœuds. À l’étape de l’évaluation, nous simulons la performance de ce mécanisme à l’aide d’un simulateur Omnetpp.

Mots Clés : Réseau Adhoc véhiculaire, streaming vidéo, Cloud Computing, Fog Computing, Qualité de service, Qualité d'expérience, Fog computing véhiculaire.

ملخص

تعد شبكة المركبات عنصرًا أساسيًا في أنظمة النقل الذكية، والتي أصبحت مجالًا مهمًا للبحث، وذلك بفضل التغييرات التكنولوجية في السنوات الأخيرة. تتكون هذه الشبكات بشكل عام من كيانات ثابتة وكيانات متنقلة. الهدف الرئيسي هو ضمان مستوى موثوق من السلامة على الطرق وجانب مريح من السفر. مع تطور قدرات الإنترنت، أصبحت المركبات أكثر ذكاءً على الطريق، حيث ظهرت مجموعة جديدة من التطبيقات الحديثة في شكل اتصالات وإدارة وتحكم. تسمح هذه الخدمات للمركبات بالتواصل ونشر معلومات السلامة من خلال الرسائل ومقاطع الفيديو، وكذلك للجانب المريح للسفر باستخدام دفق الفيديو والتطبيقات الأخرى. في الواقع، يتم استضافة هذه الخدمات على بنية تحتية حديثة مصممة للاتصالات مثل الحوسبة السحابية. أدى هذا التقارب إلى ظهور نماذج جديدة مرتبطة بالمركبات، وهي الحوسبة السحابية للمركبات وحوسبة ضباب المركبات. على الرغم من هذه التطورات، لا يزال نشر الرسائل في معظم سيناريوهات المركبات يمثل تحديًا كبيرًا بسبب تأخيرات الحزم بسبب الحركة العالية للمركبات على الطريق، والتغييرات المتكررة في الطوبولوجيا والكثافة العالية للمركبات، مما يؤدي إلى أحداث الطريق وتكرار حزمة الخسارة. تم الاشتراك في الهدف من هذه الرسالة في سياق تطبيقات حوسبة ضباب المركبات.

على الرغم من حقيقة أن دفق الفيديو هو التطبيق الأكثر دعمًا وحساسية للشبكة أثناء القيادة، فإننا نقترح نظام التحكم في حركة مرور الشبكة لدفق الفيديو عبر المركبات على أساس إنشاء شبكات افتراضية. هذه الشبكة الافتراضية هي مجموعة فرعية (مجموعة) من العقد التي تتصل ببعضها البعض لتحقيق توجيه فعال للمعلومات لحزم دفق الفيديو. تتكيف هذه الآلية مع التغيير في الهيكل والحركة العالية للعقد. في مرحلة التقييم، نقوم بمحاكاة أداء هذه الآلية باستخدام محاكي.

كلمات البحث : شبكة المركبات المخصصة، دفق الفيديو، الحوسبة السحابية، حوسبة الضباب، جودة الخدمة، جودة الخبرة، حوسبة ضباب المركبات.

Dedication

To my father and my mother,

To my sisters, to all my family,

To my supervisors in this work,

Dr. Sahraoui Abdelatif and Dr. Merzoug Soltane

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I am one of those people who firmly believe that there is no strength or power except through God. My thanks go first of all to Almighty God for the willpower, health and patience that has given me during the work period.

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List of Acronyms

ABS	Anti-lock Braking System
AODV	Ad hoc On Demand Distance Vector
ASTM	American Society for Testing and Materials standardization company
AU	Application Unit
AVC	Advanced Video Coding
B-frames	Bi-directionally predictive-coded frame
CC	Cloud Computing
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
DAB	Digital Audio Broadcasting system
DFR	Decodable Frame Rate
DSDV	Destination-Sequenced Distance-Vector Routing
DSRC	Dedicated Short Range Communications
DVB	Digital Video Broadcasting system
EA	Authorized Entity
EC	Erasure Coding
EPER	Effective Packet Error Rate
ESP	Electronic Stability Program
FCC	Federal Communication Commission
FEC	Forword Error Correction
FMO	Flexible Macroblock Ordering
GPSR	Greedy Perimeter Stateless Routing
HEVC	High Efficiency Video Coding
I-frame	Intra-coded frame
IaaS	Infrastructure as a Service

IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IPv6	Internet Protocol v 6
IT	Information Technology,
ITS	intelligent Transportation System
ITU	International Telecommunication Union
IVC	Inter-Vehicle Communication
LLC	Logical Link Control
LTE	Long-Term Evolution
MANET	Mobile Adhoc Network
MBs	Macro-Blocks
MDC	Multiple Description Coding
MDP	Mean Dissatisfaction Period
MN	Mobile Nodes
MOS	Mean Opinion Score
MPEG	Motion Picture Expert Group
MSE	Mean Squared Error
NC	Network Coding
NPAD	No Program Associated Data
ns-2	Network Simulator 2
OBU	On Board Unit
OLSR	Optimized Link State Routing
OSI	Open Systems Interconnection
P-frames	Predictive frame
P2P	Point to point
PaaS	Platform as a Service
PAD	Program Associated Data
PDA	Personal Digital Assistant
PDR	Packet Delivery Ratio
PLNC	Packet Level Network Coding
PLR	Packets Loss Rate
PSNR	Peak Signal to Noise Ratio
QoE	Quality of Experience

QoS	Quality of Servise
RBF	Receiver-Based Forwarding schemes
RCP	Resource Command Processor
RDS	Radio Data System
RDSTMC	Radio Data System - Traffic Message Channel
RSU	Road Side Unit
SaaS	Storage as a Service
SBF	Sender-Based Forwarding schemes
SDN	Software-Defined Network
SLNC	Symbol Level Network Coding
SSIM	Structural Similarity Index Measure
SVC	Scalable Video Coding
TA	Traffic Announcement
TCP	Transmission Control Protocol
TP	Traffic Program
UDP	User Datagram Protocol
USP	User Satisfaction Percentage
V2I	Vehicle to Infrastructure communication
V2V	Vehicle-to-Vehicle communication
VANET	Vehicular Ad-hoc Network
VC	Vehicular Clouds
VFC	Vehicular Fog Computing
VSN	Vehicular Sensor Network
VuC	VANET using Clouds
WAVE	Wireless Access in Vehicular Environments
WLAN	Wireless Local Area Networks
WME	WAVE Management Entity
WSM	Wave Short Message
WSMP	WAVE Short Message Protocol
XOR	Exclusive-OR

General Introduction

The automobile industry has advanced significantly in recent years, and vehicles are no longer referred to as mechanical systems with electrical components. New features have been added to vehicles to help them comprehend their surroundings and interact with other vehicles, making them smarter and more connected. The goal was to process this data and make choices in real time regarding contemporary cars using cameras, on-board sensors, radar, GPS, and wireless communication devices that enables cars to interact with one another through vehicle to vehicle communication, or road units can communicate with infrastructure using vehicle to infrastructure communication.

Among the applications that have attracted a lot of interest from researchers in recent years, those that exchange information in order to increase road safety and achieve more reliability by disseminating information on the network. This information relates to congestion conditions, events, accidents, weather information, etc. On the other hand, provide a set of functions to ensure a level of comfort when traveling, such as playing games with other passengers, getting video information about nearby restaurants and hotels, assuring video conference service between passengers, Internet connections, online payment, and so on. Video streaming is one of the most recent issues addressed by the VANET research group. Instead of textual communications, video streaming services and apps in VANET may meet the needs of automobile drivers and passengers by giving a clear view of traffic or other digital data.

To support such applications, a network between these vehicles must be created. Among the major interests of these applications, the improvement of road safety, the dissemination of information, and traffic avoidance. To achieve a high level of security, these networks have become an active field of research and are characterized by the emergence of standards of communication and development work. For many vehicle applications, such as augmented reality (AR) techniques, autonomous driving, high resolution video streams, etc. These innovative applications need a huge amount of resources as well as higher communication, calculation, and storage performance. Due to the significant latency caused by the round trip between vehicles and the cloud, transferring traffic data to the cloud for processing is not possible. Cloud computing is complemented by IT fog, which focuses on moving IT resources to the edge of networks to resolve latency limitations and to allow incoming traffic to the cloud. Vehicle fog calculation focuses on the connection of vehicles with an ad hoc network and the transformation of each connected vehicle into a node of a distributed cloud platform, and it requires sufficient processing and communication capacity at the edge of networks, such as LTE base stations.

The Cloud Computing uses remote distribution servers that are geographically accessible on the Internet to carry out the main operations, namely processing, data storage and computing power. While the fog computing is a new paradigm invented as an extension of services beyond cloud computing. The Fog operations feature a decentralized environment based on location data that delivers traffic services close to vehicles, such as data processing and storage. The IT fog paradigm restricts computing to local servers for computing purposes, reducing latency and improving performance while also making it more powerful and well-organized.

The main aim of this thesis is to review the techniques of network traffic control in vehicular networks and to propose a video streaming traffic control system by integrating an approach of clustering. In particular, we proposed an algorithm which is based on the dominated set algorithm to create a cluster of virtual nodes. This virtual cluster enables video data to be broadcast efficiently, taking into account intermittent networks by allowing faster upload and download video packets. The virtual network aims to reduce latency problems experienced during high internet traffic and the rise of autonomous vehicles and to meet the demands of real-time applications.

The general structure of our work is organized into four chapters as follows :

In chapter one, we'll go over the definition of a vehicular network and the challenge of data dissemination in these networks, as well as the components, characteristics, architectures, and many applications developed in this context. Then the integration of cloud computing and IT fog services into VANETs and the convergence to the Vehicular Fog Computing (VFC) paradigm.

In the second chapter, The fundamental ideas of video streaming will be shown, including video evaluation metrics, video compression standards, and video encoding techniques. In order to assure excellent video streaming quality, this chapter featured a complete state of the art evaluation of diverse video streaming projects on Vehicular networks, including classifications, and a comparison of these various works using various transmission metrics

In the third chapter, we will propose a system that controls video streaming traffic in order to improve vehicular network performance in a vehicle fog network by integrating an approach of clustering. In particular, We suggested a dominating set algorithm to create a cluster of virtual nodes. This virtual cluster enables video data to be broadcast in real time with high quality and low latency.

In chapter four, we will highlight the simulation of the proposal in Omnet++ to describe a specific scenario for video streaming. Then we will discuss the obtained results.

Chapter 1

Introduction on Vehicular Ad-hoc Network

Introduction

Vehicular ad-hoc networks (VANETs) are a special class of Adhoc mobile networks (MANETs). These networks are characterized by communication limitations, high node mobility and rapid changes in typologies. Unlike other mobile networks, VANETs do not have energy constraints, which allows efficient data dissemination and a greater amount of data to be collected. In addition, vehicles can be equipped with sensors that are not commonly available on other mobile devices. Automotive applications can be used in many urban scenarios. For example, traffic management, detection of traffic jams, prevention of collusion, increase road safety in general.

The goal of this chapter is to learn about the concept of vehicular networks and the problem of data dissemination in these networks. We first present the basic concepts, mentioning their definition, these components, these characteristics, the architectures and the applications offered by vehicle networks. Next, we present the convergence of VANET applications towards VANET Clouds applications and the Vehicular Fog Computing (VFC).

1 Vehicular Ad-hoc Network

We present the basic concepts of Vehicular Ad-hoc Network (VANET) in this section because our project is based on streaming video in VANET to enhance vehicle safety, manage road traffic, and increase driver and passenger comfort.

1.1 VANET Definition

In the field of wireless communication, the Vehicular Ad-hoc Network (VANET) has emerged as one of the most important research areas. Where a VANET is defined as a subset of Mobile Ad-hoc Networks (MANETs) in which the mobile nodes (MN) are cars that travel at a faster rate than the Mobile Ad-hoc Networks nodes [1].

Without the requirement for a fixed infrastructure, VANET allows vehicles to establish a self-organized network, It has several MANET properties, such as wireless communication, mobility, and decentralized control, as well as some unique properties, including a highly dynamic topology, predictability of traffic density, frequent link disconnection, and adequate storage capacity [2].

VANET includes of the mobile nodes (MN), road side units (RSU) [3]. For signal processing (data sharing) to and from RSUs, mobile nodes are sensors integrated in vehicles that are referred to as on board units (OBU). RSUs are fixed installed units that act as a communication hub between mobile nodes and servers or the internet [1].

VANET provides a number of services, the most notable of which is road safety, which uses data exchange over the internet to decrease traffic accidents [1]. A VANET network is seen in Figure 1.1.

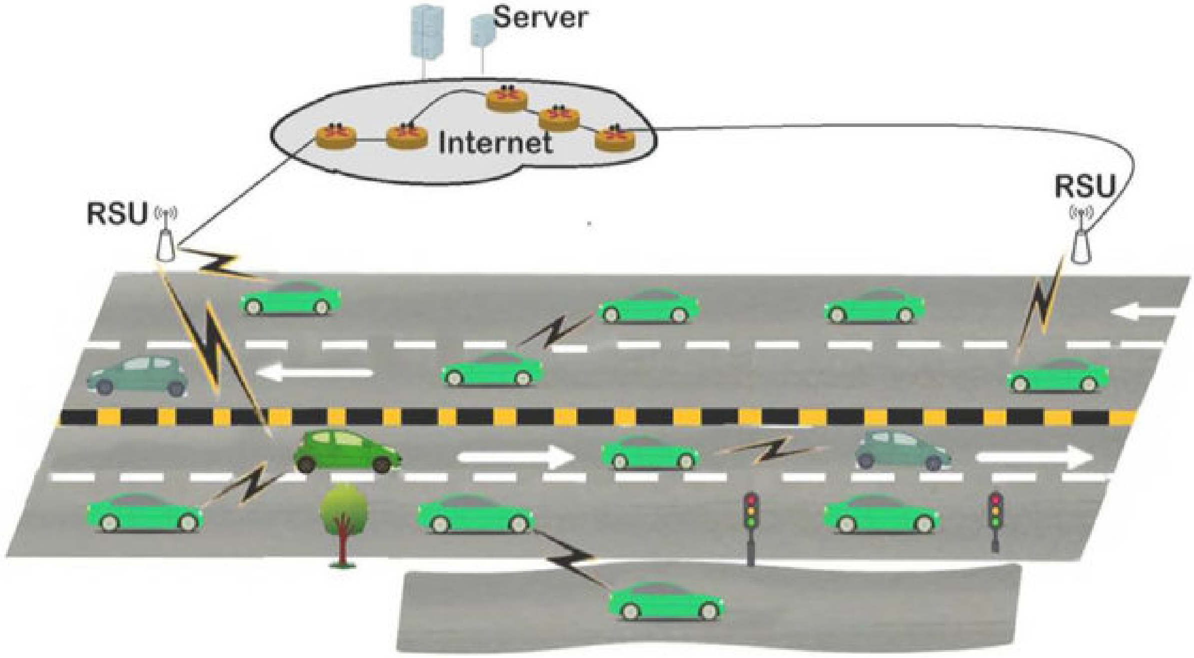


Figure 1.1 – Vehicular Ad-hoc Network [4].

1.2 VANET Architecture

A wireless media called WAVE is used to communicate between cars or between a vehicle and an RSU. [5]. This method of communication provides drivers and travelers with a wide range of knowledge and allows safety applications to improve road safety and provide a relaxed driving experience. The on board unit, The road side Units and the application unit (AU) are the three core device components [6].

The following sections examine various VANET components:

1.2.1 On board unit (OBU)

An OBU is a wave device that is normally mounted on a smart vehicle and is used to exchange data with RSUs or other OBUs. It has a resource command processor (RCP), as well as a read/write memory for storing and retrieving data, a user interface, a specialized interface for connecting to other OBUs, and a network device for short-range wireless communication using IEEE 802.11p radio technology. It might also contain a network device for non-safety applications based on IEEE 802.11a/b/g/n or other radio technologies. The OBU uses the IEEE 802.11p radio frequency channel to create a wireless link with the RSU or other OBUs, and it is responsible for communicating with other OBUs or RSUs. It also provides communication support to the AU and transmits information on behalf of other On board units on the network [6].

Wireless radio access, ad hoc and geographical routing, network congestion control, secure message transfer, data security, and IP mobility are the core tasks of the OBU [6]. Figure 1.2 shows the components of the intelligent vehicle.

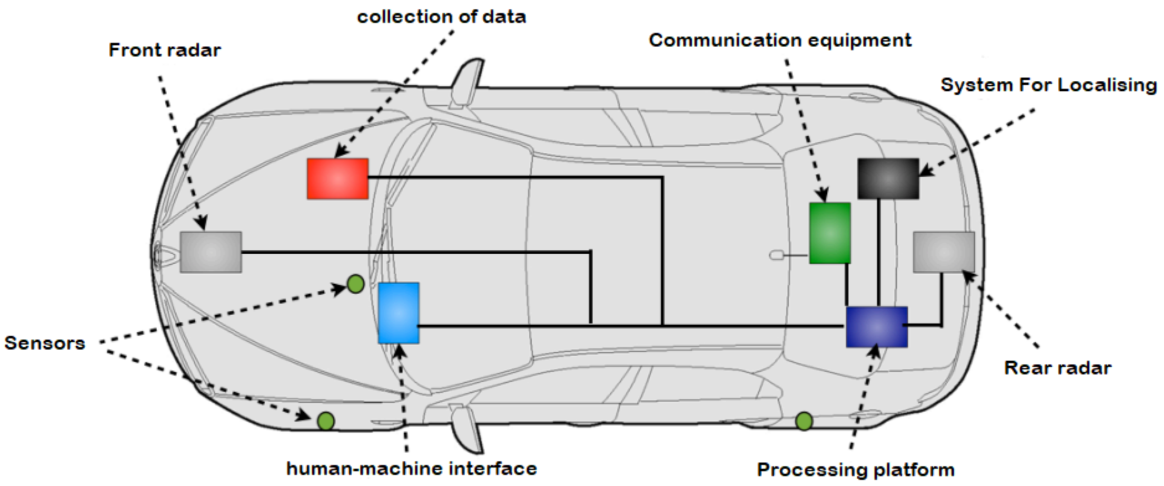


Figure 1.2 – The components of the intelligent vehicle [7].

1.2.2 Application unit (AU)

The application unit is a device installed in the vehicle that employs the provider's services in conjunction with the OBU's communication capabilities. The AU may be a dedicated device for safety applications or a regular device that runs the Internet, such as a personal digital assistant (PDA). The AU can be wired or wirelessly connected to the OBU, and it can be contained in the same physical device as the OBU. It's sensible to distinguish between the application unit and the OBU. The only way the application unit connects with the network is through the OBU, which is in charge of all mobility and networking operations [6].

1.2.3 Road side Unit (RSU)

The RSU is a wave device that is generally installed along the side of the road or at particular areas such as crossroads. The RSU comes with one network device for specialized short-range communication using IEEE 802.11p radio technology, and it may also be expanded to include other network devices for communication inside the infrastructure network [6].

The following are the major functions and operations connected with the RSU, according to Communication Consortium:

1. Redistributing information to other OBUs and transmitting information to other RSUs so that it can be transferred to other OBUs to extend the ad hoc network's communication range.
2. Using infrastructure to vehicle communication and serving as an information source to run safety applications such as a low bridge alert, accident warning, or work zone.
3. Connecting On-Board Units to the Internet.

1.3 The communication environment and the mobility model

Vehicular networks require greater environmental diversity to be taken into account. Due to the mobility of vehicles, it is possible to switch from one urban environment characterized by numerous obstacles to the propagation of signals, to a peri-urban or motorway environment with different characteristics.

In addition to this environmental diversity, vehicle networks are also distinguished from ordinary wireless networks by a mobility model of which one of the most obvious translations is the high speed of the nodes, which considerably reduces the duration of time during which the nodes can communicate.

1.4 The communication model

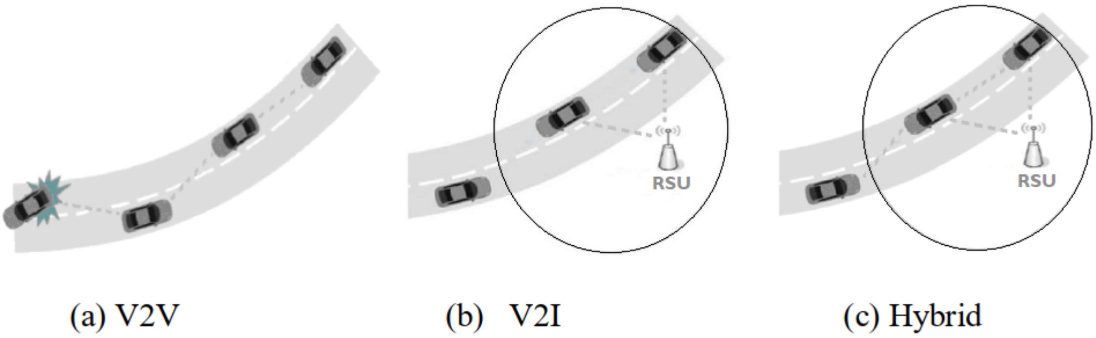
Vehicle networks were mainly designed for applications related to road safety (eg dissemination of warning messages). In this type of application, communications are made almost exclusively by successive linking of a source to a multitude of recipients. As a result, the broadcast or multicast transmission model is referred to as the dominant model on vehicle networks.

1.5 The size of the network

Given the significant advances made in the area of wireless communications wire and the low costs of associated equipment, vehicles that already integrate massively GPS systems and Bluetooth equipment will most likely be equipped massively, communication platforms allowing them to constitute real networks. In doing so, and given the everincreasing importance of density and of the vehicle fleet, we can expect the size of the vehicular networks including deployments are still very confidential, on a whole different scale. The importance of the potential size of vehicular networks is therefore a major aspect to consider while designing these networks.

1.6 VANET Communications

The VANET architecture allows connectivity between vehicles and roadside units (RSUs) to be able to exchange various information and data related to the safety and comfort of road users. For this reason, we distinguish three types of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure communications (V2I) and hybrids:



(a) V2V (b) V2I (c) Hybrid

Figure 1.3 – Types of VANET communication [8].

1.6.1 Vehicle to Vehicle communication (V2V)

As illustrated in Figure 1.3 (a), throughout this way of communicating, The vehicles exchange information with one another. without regard for the infrastructure or the RSU. Vehicle to Vehicle (V2V) communication is a type of wireless communication with many hops in which data from the sender node travels via a series of nodes (vehicles) before reaching the recipient node. This architecture can be used in alert dissemination scenarios (emergency braking, collision, deceleration, etc.) or for cooperative driving [8].

1.6.2 Vehicle to Infrastructure communication (V2I)

The messages are exchanged between the vehicles and RSUs that are deployed in the surrounding networks [9]. With the cars in its transmission range, In a signal hop, the roadside unit receives and sends messages. Between cars and RSUs, V2I provides a greater bandwidth communication. Vehicle to Infrastructure communication can be used for a myriad of situations, including sending out periodic alert notifications of the maximum vehicle speed limit that must be followed on the road. The Figure 1.3 (b) shows an example of this communication type.

1.6.3 Hybrid communication

The combination of these two types of communication architecture makes it possible to obtain an interesting hybrid architecture [10] . In fact, the scope of infrastructure being limited, the use of vehicles as a relay makes it possible to extend this distance. For an economic purpose and by avoiding multiplying the terminals at each street corner, the use of jumps by intermediate vehicles takes all its importance. Inter-vehicle communications, on the other hand, face routing issues during long-distance transmission. Access to infrastructure can help enhance network performance in certain instances. As a result, we can see how the two kinds of communication complement one other, as well as the value of a hybrid design. The Figure 1.3 (c) shows an example of this communication type.

1.7 VANET Applications

VANET applications are categorised in a number of ways in the literature. In [11] define four types of applications according to the aim of the application:

1) Services of General Information.
2) Services for Vehicle Safety Information.
3) Individual Control of Motion.
4) Group Control of Motion.

We divide VANET applications into three different groups [12] :

***1)* Applications based on transportation safety.**
***2)* Applications that are based on transportation efficiency.**
***3)* Applications for infotainment services.**

It's worth noting that the applications focused on safety and efficiency aren't totally isolated from one another; for example, a traffic collision can produce a traffic bottleneck [13]. The table 1.1 shows a few examples of Vehicular networks applications [14].

1.7.1 Transportation safety

Due to its effect on road safety, this category is the most critical and essential for VANET services. Its goal is to minimize the number of vehicles accidents on the road [15]. The major objective is to warn drivers of potentially harmful circumstances or occurrences on the road, including as accidents, junctions, and traffic jams [16]. Approaching cars, for example, can use a basic transport safety application such as sending emergency alerts to send a warning message to adjacent vehicles in the event of an accident. When the driver of the vehicle receives the warning, the vehicle comes to a complete stop or slows down. The length of the warner messages must be reduced since transportation safety applications are susceptible to transmission delays.

1.7.2 Transportation efficiency

This group attempts to enhance traffic control on the roads through communication in order to reduce traffic congestion. For example, in a traffic jam, vehicle cooperation makes it easier for an emergency vehicle to pass. The driver can use the traffic congestion app to find the optimal routes and times to their location. This group of applications can also be used to manage crossroads and junctions in order to reduce the likelihood of an accident when cars pass through them [17].

1.7.3 Infotainment services

This group offers a series of comfort services to road users, such as access to the internet, map downloads, parking charge, and internet and mobile multiplayer gaming [18] and local billboards: commercial such as restaurant offers, presence of nearby service stations, or cultural as tourist information relating to the vehicle location. Communication standards for infotainment services applications differ from those for applications of safety and efficiency, and certain infotainment services do not require real-time constraints [19].

Table 1.1 – VANET applications: a few examples [14].

Category	**Example**
Application for transportation safety	— Warning for violating traffic signals. — Assistant for making a right turn. — Assist with stop sign movement. — At an Intersection, there is a Collision Warning. — Warning about the speed of the curve. — Electronic brake light in case of emergency. — Pre-crash detection. — Cooperative forward collision warning. — Warning about changing lanes.
Application for transportation efficiency	— On-Ramp Metering with Intelligence. — Traffic Flow Control with Intelligence. — Improved navigation and travel assistance. — Optimal speed advice (green light). — Assistants for merging lanes. — helper in the parking lot.
Application for infotainment services	— Download of musics. — Videos to watch. — Assistant on the map.

2 VANET communication standards and protocols

2.1 Dedicated Short Range Communications

The Federal Communication Commission (FCC) of the United States allocated a 75 MHz in the 5.850 GHz to 5.925 GHz of sub DSRC spectrum at 5.9 GHz in 1999 to be used exclusively for vehicle-to-vehicle and infrastructure-to-vehicle communications [20]. Seven 10 MHz channels make up the DSRC spectrum (Ch 172, Ch 174, Ch 176, Ch 178, Ch 180, Ch 182 and Ch 184). Only safety related applications use channel 178, which is a control channel (CHH). The channels 172 and 184 have been set aside for a special purpose (critical safety of life and high power public safety). The remainder of the channels (SCH) are utilized for both safety and non safety purposes [21].

In accordance with DSRC technology, the American Society for Testing and Materials standardization company (ASTM) proposed the first ASTM-DSRC standard, The physical layer is based on IEEE 802.11a, while the MAC layer is based on IEEE 802.11. Following that, IEEE specifies the IEEE 802.11p protocol family, which is based on IEEE 802.11 and ASTM-DSRC. The physical layer and the MAC layer of IEEE 802.11p were changed to allow wireless communication in vehicle networks. The IEEE then defines Wireless Access in Vehicular Environments (WAVE) , which specifies protocols for wireless vehicular communication at each layer level of the OSI model.

Figure 1.4 illustrates the FCC's allocation of the DSRC frequency bands for VANET:

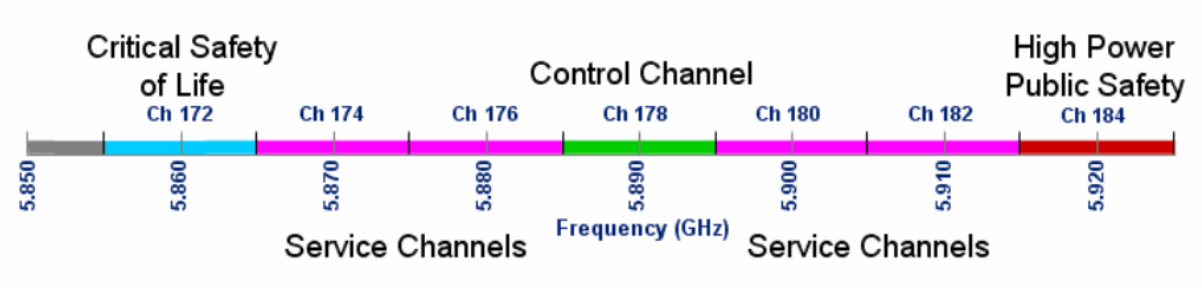


Figure 1.4 – the FCC's allocation of the DSRC frequency bands for VANET [21].

2.2 Wireless Access in Vehicular Environments

Wireless access in vehicular environments (WAVE) is a system that provides applications in an intelligent transportation system (ITS) that promote safety and convenience by providing interoperable, effective, and secure radio communications [22]. The WAVE system is meant to enable cars with direct access to other vehicles (V2V) or infrastructures (V2I) via specialized short-range communications in several ITS application scenarios (DSRC). Wireless Access in Vehicular Environments uses the IEEE 802.11p and IEEE P1609 standards (WAVE). IEEE 802.11p is used in the physical (PHY) and MAC levels of the WAVE model, whereas IEEE P1609 is used in the remaining layers. The IEEE P1609.4 standard is also used at the MAC layer [21]. The Figure 1.5 shows the WAVE architecture :

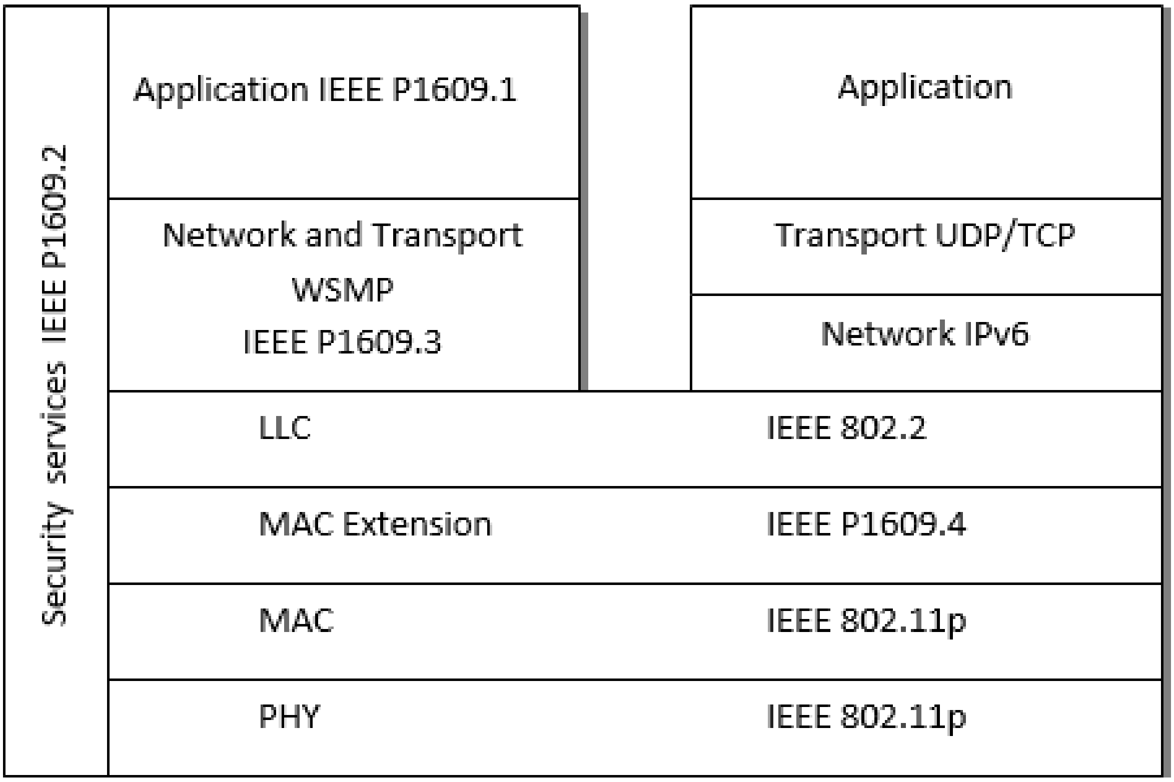


Figure 1.5 – WAVE architecture [20].

2.2.1 The IEEE 802.11p

IEEE 802.11p is an IEEE 802.11p extension standard for vehicle-to-vehicle and vehicle-to-infrastructure communications in VANETs, allowing Intelligent Transportation Systems (ITS) applications. [23]. IEEE 802.11p is a modified version of IEEE 802.11a that utilizes (CSMA/CA) Carrier Sense Multiple Access with Collision Avoidance as the fundamental media access method at the MAC layer and DSRC at the PHY layer [21]. Of contrast to IEEE 802.11a, which uses a 20 MHz bandwidth, the transmitting data rate in IEEE 802.11p ranges from 3 to 27 Mbps over a 10 MHz bandwidth [23].

2.2.2 The IEEE P1609

The upper levels of WAVE employ the IEEE P1609 standards (P1609.1, P1609.2, P1609.3, and P1609.4 : [22].

- **The IEEE P1609.1 :** The IEEE P1609.1 standard governs resource management, including services, interfaces, and security and privacy protection methods. [24].

- **The IEEE P1609.2 :** Secrecy, authenticity, and integrity are all security services provided by the IEEE P1609.2 standard for applications and management messages. This standard also specifies the format and processing mechanism for secure communications [24].

- **The IEEE P1609.3 :** The IEEE P1609.3 standard Provides networking services like addressing and routing services within a WAVE system [24]. There are two types of WAVE network services: Services for data planning and management planning. The former is compatible with IPv6 protocols and WSMP in order to send a Wave Short Message (WSM). WAVE Management Entity (WME) is the latter, and it is in charge of system configuration and upkeep [25].

- **The IEEE P1609.4 :** At the MAC layer, the IEEE P1609.4 standard adds many capabilities to IEEE 802.11p, allowing the vehicle's communication capacity to be increased and multi-channel operations to be supported [25, 26].

3 Communication techniques

There are two distinct sorts of communications : **Radio communications** and **Wireless communications**.

3.1 Radio communications

A communication system includes all the elements capable of transmitting information (sound, computer data, video, etc.) from one source to one or more destinations. Sincethe bir th of wireless networks, communications have gone from communication wired analog to digital wireless communication. Many technologies of communication can be used to ensure data exchange between vehicles, these link techniques described with radio communications [27].

The Radio Data System (RDS)

This technique is based on a broadcasting system of data by radio, it allows a continuous flow of information to be broadcast in parallel digital with FM radio broadcasts. We can cite as an example: TA (Traffic Announcement) disseminates information road. TP (Traffic Program) designates a station offering traffic guidance. RDSTMC (Radio Data System - Traffic Message Channel) media. Vehicles fitted with receivers RDSTMC can receive messages at a rate of 20 per minute. This communication mode is suitable for medium distance links (from 10 to 100 km) [28].

The Digital Audio Broadcasting system (DAB)

It is a sound transmission system digital, Two frequency bands are allocated to terrestrial DAB: band III in the frequency interval 174 - 230 MHz and the band used in France, which is between 1452 MHz and 1467.5 MHz. In addition to digital quality sound, it can be broadcast through the media DAB for text or graphic data services. This is either data inserted into the audio component itself and which are called PAD (Program Associated Data) or data broadcast by an independent audio channel and these are the NPAD (No Program Associated Data) [29].

The Digital Video Broadcasting system (DVB)

The DVB standard specifications define a set of means for the dissemination of all types of data, accompanied by information about them, in all types of media [30].

3.2 Wireless communications

Wireless communication technology is still in its infancy. There are a few technologies that are utilized in inter-vehicle communications that we can identify [29]:

- Repurposing existing infrastructure, upgrading 2G cellular networks to 3G, and other advancements (GSM, GPSR, 3GPP...).

- Wireless local area networks (WLAN) which are mainly made up of IEEE standards.

Wifi (IEEE 802.11), WiMAX (IEEE 802.16), and IEEE 802.11p are all wireless networking standards (DSRC). In the vehicle environment, wireless communication is based on two equipment entities: the first is a device located on important infrastructure sections (stops, junctions, etc.) and the second is that found on board the vehicle [31].

4 Introduction to the dissemination of messages

4.1 Dissemination

The dissemination of messages in vehicular networks consists of routing messages via the vehicular network, taking into account the network characteristics: network size, node speed, case (warning or control message). The message will be sent from one vehicle to another or to several, in a reliable manner and in a short time.

4.2 Types of message

The nodes that form a vehicular wireless network will generate and exchange messages. Depending on the application and the environmental context, a vehicle has the ability to transmit and receive control, warning, and other messages [7].

Control message

The control message is sent out on a regular basis. Traditionally, every vehicle sends out a control message every 100 milliseconds. This message, also known as a beacon, provides the transmitting vehicle's position, direction, speed, and route. Each vehicle generates a local view of the area thanks to the messaging control. Accidents or traffic jams can also be predicted and avoided by the vehicle. The control message is the equivalent of the HELLO message in routing protocols. Each vehicle is therefore know of its direct vicinity. Of course, control messages are not forwarded and use a jump broadcast [7].

Alert message

When an incident is identified, an alert message is created. This might be due to the discovery of an accident, a barrier, or the receipt of another alarm message. To ensure the warning's long-term viability, the alert messages must be sent at regular intervals. So, the vehicle (s) designated for the re-transmission of messages will issue alerts at regular times. The alert messages must therefore be reduced in size to be transmitted as quickly as possible. The messages contain in particular the coordinates of the place of the accident and the re-transmission area settings [7].

Other messages

All messages that aren't alerts or warnings are grouped together in this category. These messages are generally not repeated at regular intervals. This for example, a financial transaction message or sending an e-mail. All received messages will be stored in a cache of recently received messages. Each message will be associated with a lifetime in the cache [7].

4.3 Dissemination Types

Dissemination can be classified into two types [32]:

Dissemination for comfort applications

Because of the variety of applications available, comfort applications require a large amount of bandwidth. For instance, messaging, downloading files, playing online games, and so on. As a result, you must optimize bandwidth, and message content could be dynamic and modifiable during transmission from one knot to another [32].

Dissemination for emergency messages

Road safety applications make the roads more secure. Protocols of dissemination must take into account the constraints of sending messages in an emergency. The dissemination must ensure the spatial and temporal constraints, it is necessary that all vehicles inform vehicles close to the emergency (accident, fog, snow, etc.) [32].

4.4 Dissemination strategies

Broadcasting

A message sent by a vehicle will be transmitted to all the neighbors, then these neighbor retransmit the message, until arriving at its destination (s). This approach is among the most used for the dissemination of information on VANET networks, because it requires no information about the vehicles surrounding the transmitter. Each recipient vehicle receives several messages for this it ignores the reliability of information and increases the rate and speed of dissemination, but also it requires a communication channel access and bandwidth consumption competition [33].

Probabilistic

To communicate with other vehicles, vehicles using this strategy use their knowledge, history, and data collected on the location and mobility of other network nodes. The objective of this method is to decrease the amount of messages broadcast between two vehicles before choosing on a route for information dissemination [33].

Geographical

Each message contains necessary information about the sending vehicle, for example, message and location data. The latter will be used in this approach to get the message out. These messages are broadcast periodically. Yes, a nearby vehicle is proactive, otherwise it will be broadcast on demand in the approach reactive. Each node saves the routing history to the other nodes neighbor in a table that will be updated regularly and then they use that table to determine the shortest route to reach the destination. Therefore, this reduces the sending time. This approach can notably warn vehicles who are threatened with a probable accident in a way using these coordinates geographical [33].

Resource-oriented channel

Despite the characteristics of VANETs nodes are better compared to others MANETs network nodes (energy, processing and storage capacity, etc.). There remains the problem of access to the communication channel, because the resources of communications are limited, there are several solutions in this approach, among these solutions to mention this one, the improvement of message reception rates by allocating part of the bandwidth, each vehicle sends an impulse signal before sending the actual message [33].

Message priority oriented

There are solutions that suggest an adaptation to the dissemination of information based on the importance of information carried in the message exchanged to assure the quality of service of the applications supplied in VANETs. To avoid automatic message deletion in the event of a collision [33].

5 The convergence of VANET applications to VANET Cloud Services

5.1 Cloud Computing

Cloud Computing (CC) is a network access architecture intended at transparently and widely distributing a large number of computing resources. A service provider rents them to digital consumers, generally through the Internet [32]. Cloud computing is seen as a business model rather than a technology. The authors conducted a state-of-the-art survey by answering the question of whether cloud computing is going to stay or whether it is one of the passionate topics that will inevitably be forgotten in the next few years. Most tech market players, such as Google, Amazon, and

Microsoft, are speeding up their cloud computing efforts by offering services to their users [34].

5.2 Combination of VANET and Cloud Computing

Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) network designs are the most dependable and secure solutions for ensuring efficient communication and traffic control. The construction of a VANET network that meets current demands might be difficult due to the data's dispersion nature, different paradigms, and communication sessions. In MANETs, nodes self-organize to create a network without the support of the current infrastructure (RSU). So CC is supposed to be a new solution to dealing with these problems. Indeed, its strength lies in its scalability, PaaS (Platform as a Service), IaaS (Infrastructure as a Service), SaaS (Storage as a Service) and several other important features. Cloud computing emerged from the understanding that rather than investing in infrastructure, businesses could find it more cost-effective to lease the equipment and, in some cases, the software required to operate their applications. Cloud computing's scalable access to ITnomenclatureITInformation Technology, resources, and services is one of its biggest advantages [35].

5.3 Using Clouds in VANETs

The CC may be utilized as a Network as a Service on the VANET network. The internet isn't available in every automobile on the road. Cars having Internet connectivity can offer extra capacity to other vehicles on demand in NaaS. It is clear that many drivers will have constant Internet connection while driving, thanks to cellular networks and other fixed access sites. Although some cars do not have Internet access, they will need to use the Internet. In such circumstances, each driver with an Internet connection who wishes to share this resource will announce this information to all surrounding vehicles. Or Storage as a Service (SaaS). Vehicles having a big storage capacity share storage with other vehicles that require temporary storage capacity in SaaS mode [35].

5.4 VANET Cloud architectures

Vehicle Clouds (CV), Vehicles Using Clouds (VuC), and Hybrid Clouds are the three main architectures of VANET Clouds (HC), each section will be developed in the subsections next [36]:

5.4.1 Vehicular Clouds (VC)

The following describes how Vehicular Clouds (VC) are produced. To begin, the cars launch a protocol for selecting one or more brokers and determining the boundaries of Clouds by picking an Authorized Entity (EA) among the brokers to seek authority to build a cloud. After the nodes and AE have been selected, AE invites the vehicle nodes inside the Cloud boundary's premises to join the cloud. Vehicles that are interested will react with an acknowledgement. If the number of interested cars reaches a particular threshold, AE will request permission from higher authorities to establish a cloud and supply possible resources. After receiving authorisation, cloud members will pool their resources to create a rich virtual environment. AE submits the calendar to the authorities for approval and execution. Higher authorities may entrust the task in progress to the cloud in return for particular incentives given to participants. When the work is finished, AE dissolves the cloud [36]. The Figure 1.6 describes the architecture of Vehicular Clouds.

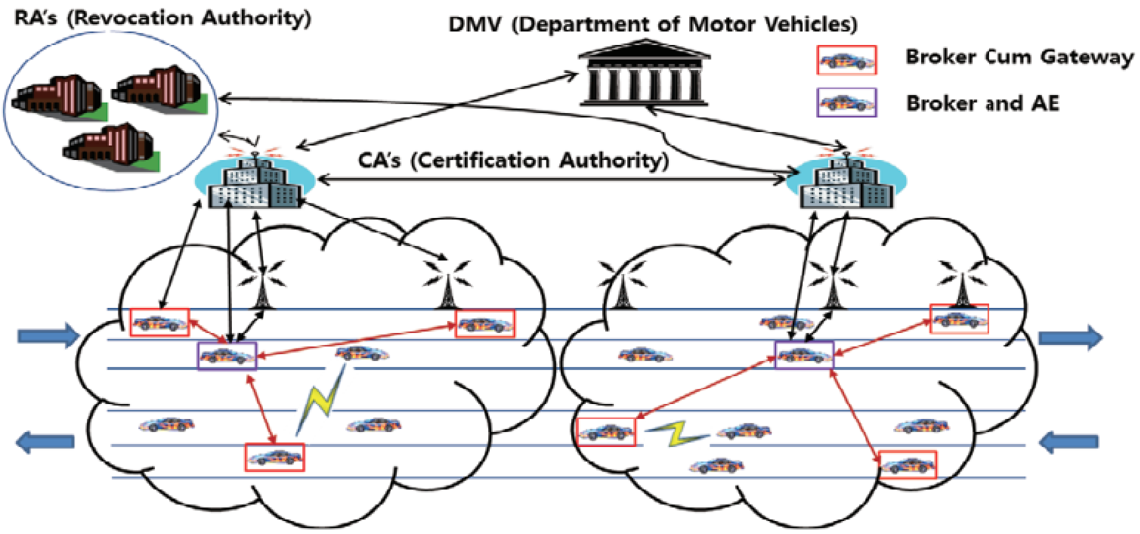


Figure 1.6 – Vehicular Clouds (VC) [36].

5.4.2 VANET using Clouds (VuC)

The VANET utilizing Clouds (VuC) architecture is built on VANET's use of cloud services, as depicted in Figure 1.7. A virtualization layer is available on the gateways. RSUs provide as access points for cars to cloud services.From RSUs to cloud services, high-speed wired connectivity may be employed. VuC's services include real-time traffic statistics and a multimedia information system, as specified in the VANET cloud taxonomy [36].

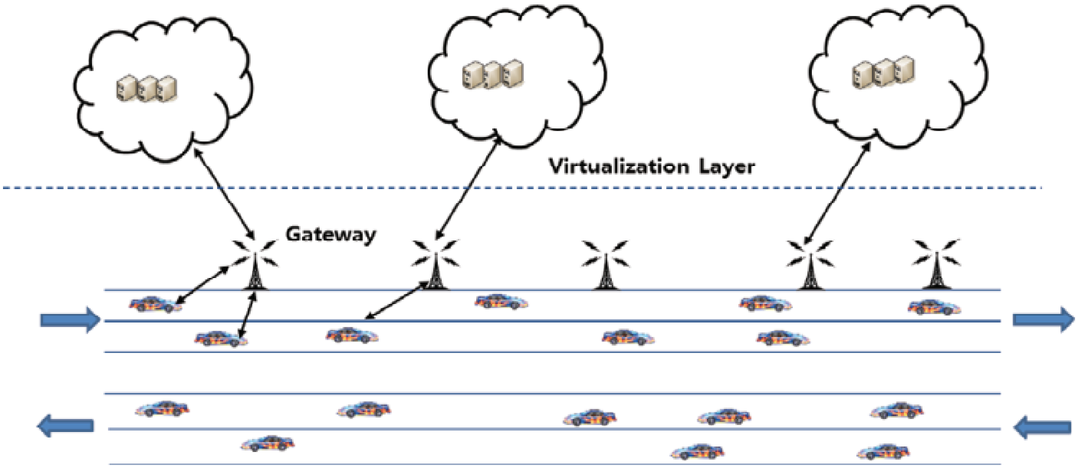


Figure 1.7 – Vehicles using Clouds (VuC) [36].

5.4.3 Hybrid Clouds (HC)

Hybrid Clouds (HC) are a hybrid of VC and VuC, in which the VC serves as both a supplier and a consumer of services. The HC architecture is seen in Figure 1.8. The idea behind HC is that on-the-road cars may wish to rent their resources while also accessing cloud services. The most important examples of such situations are NaaS and P2P. Despite this, vehicle node connection is spotty due to the transient nature of VANET. However, it might be claimed that the file sizes for P2P applications are often tiny, making them suited for short-term connections. IaaS in the case of VC is another possible application for this architecture [36].

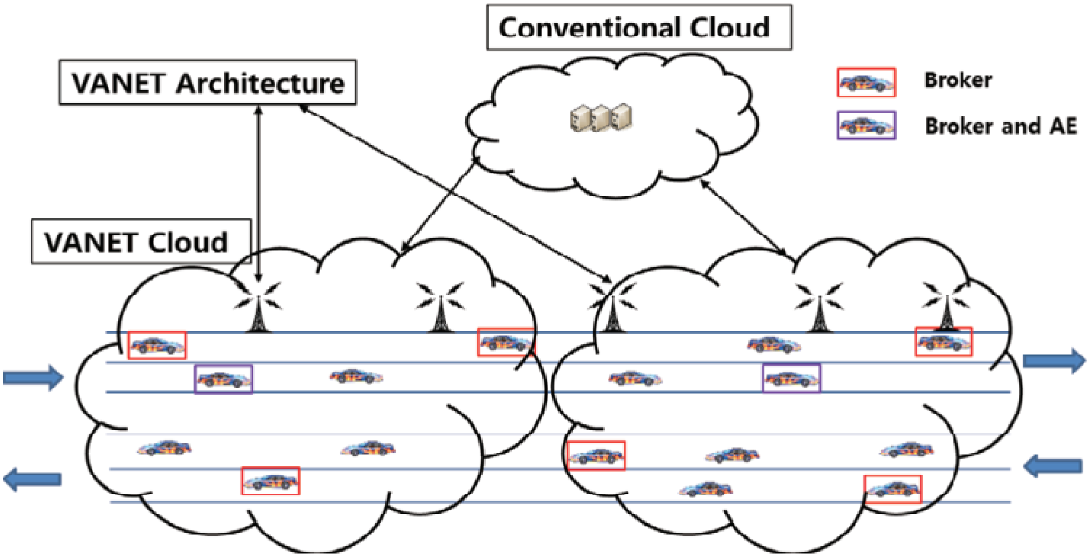


Figure 1.8 – Hybrid Clouds (HC) [36].

5.5 VANET Cloud applications

Remote Configuration and Car Performance Checking

A vehicle may be remotely watched and debugged using cloud technologies. Hyundai, a well-known vehicle manufacturer, has previously deployed this technology to monitor its cars on the manufacturing line. The car's performance is monitored remotely by receiving data from it on a regular basis, and this information is utilized to deliver high-quality services to consumers. However, with such an approach, the privacy of users and whereabouts is a big problem [34].

Big traffic data analysis

Vehicles generate a significant quantity of traffic data. Tag messages, for example, provide data on a millisecond scale, which is useful for VANET's services. The storing and processing of data would need a significant amount of storage and computer power. This information might be utilized for anything from traffic updates to entertainment [34].

Smart location-based advertisements

With the introduction of smart automobiles, roadside billboards may be replaced with an in-car advertising system in which drivers may receive announcements tailored to their preferences. As previously stated, cloud decision servers may employ location data, driving models, and driver location queries to intelligently announce events and/or places to consumers based on their preferences [34].

Vehicle Witnesses

A researcher has presented a vehicle witness solution (VWaaS), which uses cloud infrastructure to back up original forensic evidence in the case of a road accident. The vehicles capture photographs of the place of interest and send them to the cloud when they detect an occurrence or get orders from the authorities. The cloud infrastructure records these images as forensic evidence and later provides forensic information to law enforcement, justice and/or insurance agencies [34].

5.6 Vanet Cloud Problems and Challenges

While VANETs have solved many present problems by leveraging the cloud, as the number of smart cars and autonomous vehicles grows, certain basic obstacles and concerns must be addressed.A few key problems and requirements for future VANETs have been identified. Future VANETs and their applications will change throughout time, integrating new emerging and new technology and introducing new functionality.

The following are some of the major problems that future VANETs will face:

Intermittent connectivity

Controlling and maintaining vehicle and infrastructure network connections is a major problem. In automotive networks, intermittent connectivity and delay induced by high vehicle mobility or high packet loss rates must be reduced and avoided [37].

Location awareness and high mobility

Future cars will need a location awareness and high level of mobility among the vehicles cooperating in communication. In order to collaborate in emergency circumstances and identify events, each car in the same network should be aware of the accurate position of other vehicles in the same network [37].

Management of heterogeneous vehicles

There will be a large number of heterogeneous smart automobiles in the near future. Another issue for the future internet of cars is the control of diverse vehicles and their intermittent connectivity [37].

Security

The threat to user data, content, and location privacy is always present. V2V or infrastructure is how vehicles interact with one another, and V2I should let users to select what information is shared and what is kept private. Instead of transferring sensitive data to a cloud data center for processing, it's simple to ensure privacy by reviewing it locally [37].

Support of network intelligence

The necessity to maintain an intelligence network is one of the problems that future vehicular networks will confront. Vehicles will be outfitted with a large number of sensors in future VANETs, and the edge cloud will gather and reprocess data before delivering it to other sections of the network, such as traditional cloud servers [37].

Real time application and low latency

In terms of real-time application requirements, low latency is the most basic issue that future VANETs will face. Future VANETs should be able to handle real-time applications with very low latency, such as safety and emergency alerts, video streaming, and so on [37].

High bandwidth

High-quality video streaming, augmented reality, and other comfort applications will be in high demand in the future. Furthermore, traffic applications like 3D maps and navigation systems require automated updates on a frequent basis [37].

Connectivity

Future VANETs will demand fulfilling the network's high communication requirements, which will necessitate flawless connectivity between all linked cars. All nodes of the network, including as automobiles and fog devices, should ensure continuous and highly reliable communication between connected and autonomous vehicles. It must be capable of preventing packet loss and transmission faults in the communication system [37].

6 Fog Computing

Cisco Systems, Inc. engineers were the first to present and propose fog computing. It's a subclass of the cloud computing paradigm at the edge of wireless networks for IoT devices [38]. The fog computing architecture is driven by the OpenFog Consortium. Its goal is to persuade standard-setting bodies to establish standards that allow edge devices to securely communicate with other edge devices, such as IoT and cloud services [39]. Smart device mobility, low latency, and location awareness are not met when IoT applications are implemented in a traditional cloud's two-tiered architecture. As a result, the evolution of multi-tiered fog computing architecture is being investigated. In general, users must download their data from the cloud (multimedia files, documents, and so on). Data will be stored on fog servers near users, which will reduce latency and increase throughput. On the first tier, the ITS application is deployed in cars. TThe fog platform is the second tier, which comprises fog devices such as RSUs and wireless access networks. The conventional cloud's hyperscale data center is the third layer. Fog computing in cars enables high bandwidth, low latency, location awareness, and Quality of Service (QoS) for streaming and real-time applications [30]. Resource virtualization is used in fog computing, with hypervisors for input/output resources and computing, virtual file systems for storage, and a Software-Defined network (SDN) for network virtualization infrastructure [40]. Figure 1.9 shows a comparison of the number of hops, latency, and bandwidth from edge nodes to the cloud:

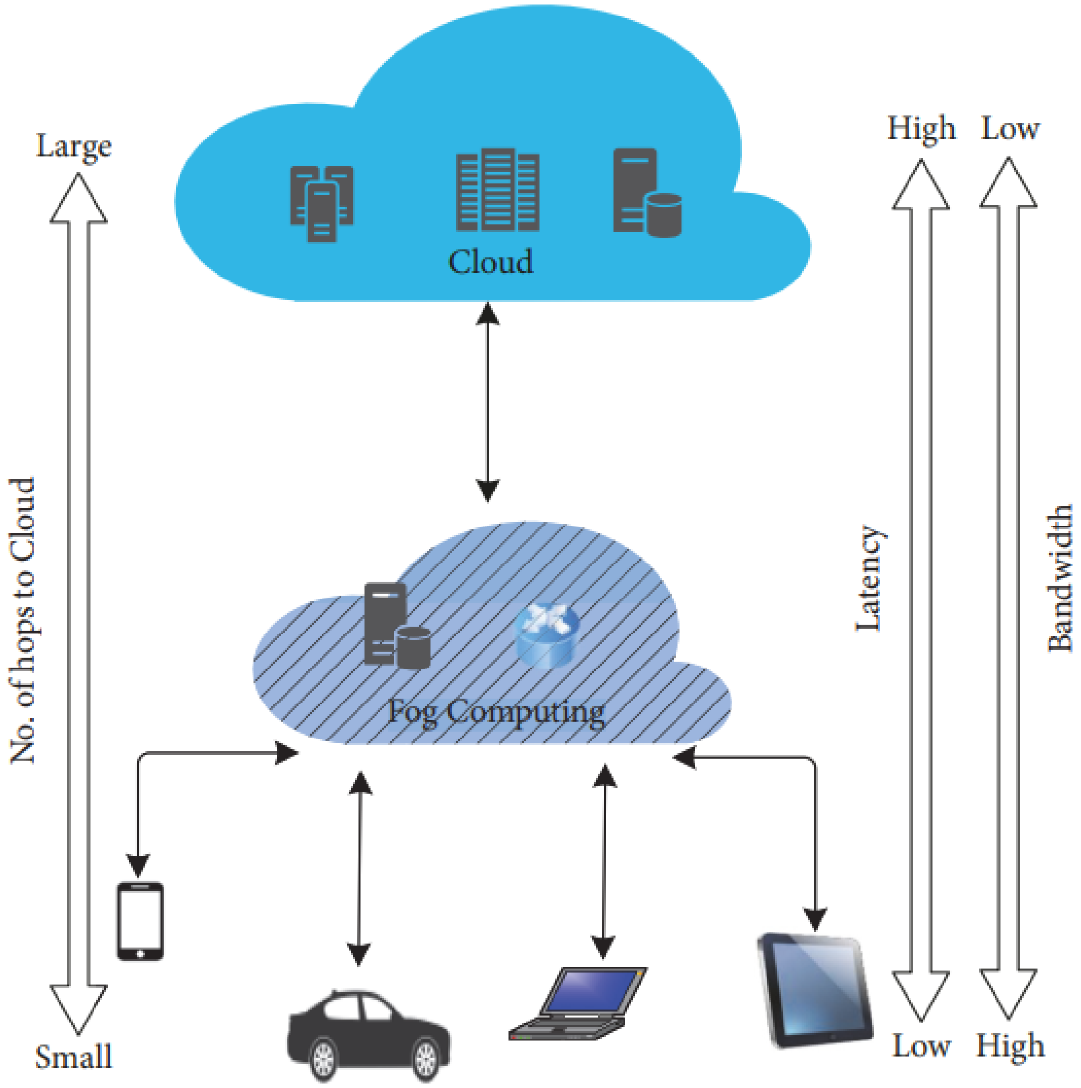


Figure 1.9 – Comparison of the number of hops, latency, and bandwidth from edge nodes to the cloud [37].

7 Vehicular Fog Computing

Vehicle fog computing (VFC) applies the fog computing concept to traditional vehicular networks, providing communication, compute, and storage capabilities at the network's edge. As an intermediary layer between the cars and the cloud server, a fog server layer is established. Communication and computation include end users and vehicles as well. It is designed for applications that have a large number of users and demand a lot of resources as well as robust communication and computation support. Vehicles serve as infrastructure to satisfy communication and computation demands in this paradigm, which is an architecture that carries out communication and computation utilizing a collaborative multiplicity of enduser clients or near-user edge devices. Techniques such as augmented reality (AR), self-driving, video streaming, and other novel uses are all on the horizon. They all deal with complex data processing and storage procedures that need a greater degree of data transmission, computation, and storage. This poses major challenges for present car networks, especially in terms of communication and computing power [41]. A high-level architecture of vehicular fog computing is presented in Figure 1.10 :

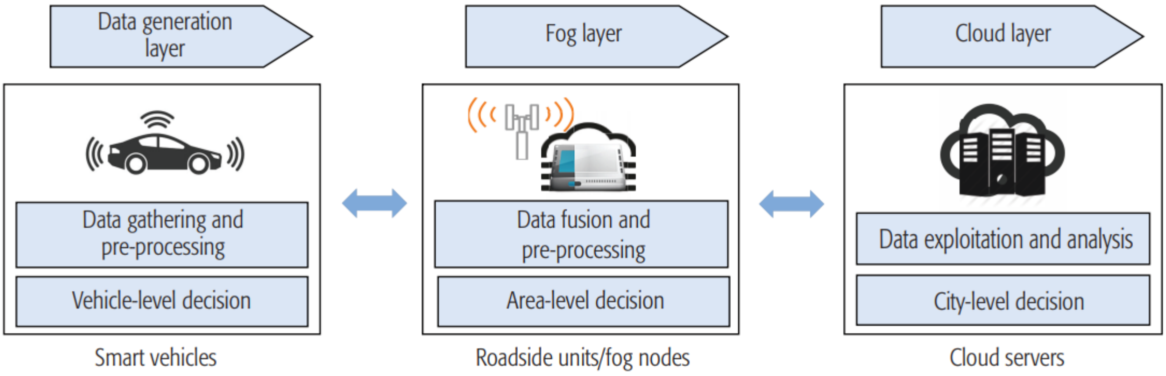


Figure 1.10 – Architecture of vehicular fog computing [41].

Conclusion

In this chapter, we present an introduction to vehicular networks. Firstly, we present the key concepts of VANET networks, their characteristics and the different applications developed in this context. Then we mention the techniques for the dissemination of messages on a VANET network. Finally, the integration of Cloud Computing and information technology fog services in VANETs and the convergence of to Vehicular Fog Computing (VFC) paradigm.

In the following chapter. The fundamental concepts of video streaming will be presented, includes video compression standards, video encoding techniques, and video evaluation measures, and related approaches on video streaming on VANET.

Chapter 2

Video Streaming over Vehicular Ad-hoc Network

Introduction

Vehicular Ad-hoc Network (VANET), is a crucial technology of Intelligent Transport Systems (ITS). It is a special class of Mobile Ad-hoc Network (MANET). Other terms used to describe VANET are Inter-Vehicle Communication (IVC) [42] and Vehicle-to-Vehicle communication (V2V) [43]. A VANET, on the other hand, includes communication not just between vehicles but also between a vehicle and a static infrastructure installed along the route. For vehicle communication, government agencies have designated particular frequency bands.

Furthermore, streaming video in the VANET is a critical component in the development of many services. With a camera installed on the vehicle or at an RSU, road events such as accidents, road congestion, and traffic conditions can be captured and recorded in a video file, which can then be transmitted to various Vehicular networks nodes. However, video transmission in VANET is a critical issue in this area due to the unique characteristics of VANET, such as high vehicle mobility, short link service life, and network overload, as well as video broadcasting requirements, such as shorter transmission times and higher data reception rates.

The foundations of video streaming are covered in this section, which includes video assessment criteria, video encoding techniques, and video compression standards.

1 Video streaming definition

Video streaming is a sort of media streaming in which information from a video file is transmitted to a remote user in real time via the internet. You may use streaming to view movies or listen to music via the Internet. without downloading any files [44]. Streaming video is a popular method of watching TV episodes, snippets, and full-length movies over the Internet. Smart TVs, media hubs, laptops, and mobile devices may all stream the content [45].

2 VANET features

Vehicle density fluctuations and environmental obstacles are also troublesome for streaming video because they interfere with and disrupt the sender-receiver communication channel when the video is delivered, because of the high dynamic of VANET topology owing to the high speed of automobiles. As a result, these circumstances may cause network congestion and transmission mistakes, lowering video quality [46, 47].

3 The metrics of Video streaming

The evaluation criteria for video streaming may be classified into two categories: objective assessment and subjective evaluation assessment [48]. To evaluate video quality, objective evaluation may be done automatically utilizing a collection of information such as network technical data, Subjective evaluation, on the other hand, is concerned with a person's perspective and experience. A group of human observers is requested to watch and rate the video quality in subjective evaluation; the Mean Opinion Score (MOS) is the average of all human judgments [49]. The International Telecommunication Union (ITU) provides five categories of picture quality and image degradation in the ITU-R BT.500-11 recommendation [50], which assist humans in classifying seen images. the ITU-R picture quality and degradation scales are shown in Table 2.1.

Table 2.1 – the ITU-R picture quality and degradation scales [50].

Scale of Grading	**Quality of the image**	**Image impairment**
1	Bad	Very annoying
2	Poor	Annoying
3	Fair	Slightly annoying
4	Good	Perceptible, but not annoying
5	Excellent	Imperceptible

The subjective assessment, which is the better measure for evaluating video quality, gives a more trustworthy judgment than objective assessment, which is the better metric for evaluating video quality. In contrast to objective evaluation, The significant cost and time necessary to evaluate video quality limits subjective streaming video evaluation.

Video streaming metrics are divided into two main categories in VANET: Quality of Service (QoS) and Quality of Experience (QoE).

3.1 Quality of Service metrics (QoS)

The Quality of Service (QoS) is based on an objective evaluation of streaming video, and It's been described in two different ways: as a user and as a network provider. QoS is defined in the user context by qualities that are critical to the service's usage, whereas QoS is defined in the network provider context by parameters that contribute to the service's end to end performance and must represent the user's expectations. [51].

Several studies have used QoS measures including Packet Loss Rate (PLR) [52], Peak Signal to Noise Ratio (PSNR) [48], transmission delay, jitter, and throughput to assess video streaming quality in VANET. In this part, we'll go through some of the QoS measures that are utilized in VANET to evaluate video streaming, as described in table 2.2.

Video frame rate distortion

The following equation (2.1) is used to determine the rate distortion (Dd) of video frames according to [53]:

$$Dd = De + Dv \tag{2.1}$$

Where (De) represents signal compression distortion and (Dv) exhibits inter-frame error propagation distortion and residual errors. Authors of the [54] presented the following equation (2.2) to rebuild the VANET video streaming rate distortion equation, where the video is sent over many hops of communication:

$$Dd = De + Dn \tag{2.2}$$

Here (De) denotes encoder signal compression distortion and (Dn) denotes network distortion, (Dn) is computed using the following equation (2.3):

$$Dn = Dparti + Dexpir + Derror \tag{2.3}$$

Where ($Dparti$) is the distortion brought on by network partition, ($Dexpir$) is the distortion caused by video deadline expiry, and ($Derror$) is the distortion produced by wireless fading channel and interference transmission error.

Start-up delay

Each vehicle in a VANET has a buffer to store received packetsand video playback is split into two phases: charging and playback. The charging phase begins when the buffer is empty and consists of charging the buffer with sufficient packets; the playback phase begins when the buffer is completely charged (playback threshold). The time difference between charging stages is known as the start-up delay. The equation (2.4) gives the start-up delay (Ds) according to [55]:

$$Ds = min\{t|X(0) = 0, X(t) = b, t > 0\} \tag{2.4}$$

Where $X(t)$ denotes the number of packets in the buffer at a given time (t), and (b) denotes the playback threshold. The equation (2.5) gives the average start-up time:

$$E(Ds) = b/\lambda \tag{2.5}$$

Where (λ) is the packet arrival rate at the target vehicle.

Frequency of streaming freezes

When the effective video streaming arrival rate at the receiver automobile (λ) is less than the vehicle's playback rate (μ), the playback phase will likely halt, resulting in video streaming interruptions (streaming freezes) at the application layer. According to equation (2.6), the average number of streaming freezes after (t) seconds $(E(F))$ is as follows [55]:

$$E(F) \approx -(\lambda(\lambda - \mu)/\mu b) * t \tag{2.6}$$

Packet Delivery Ratio (PDR)

PDR is defined as the total number of received video packets divided by the total number of transmitted video packets. The following is the formula (2.7):

$$PDR = \frac{\sum ReceivedPackets}{\sum SendPackets} \tag{2.7}$$

Average transmission delay

The transmission delay of a packet is the time gap between the sending moment of a packet at the sender and the complete receipt time of that packet at the receiver level. The average transmission delay is calculated by multiplying the sum of all received packet delays by the total number of received packets. The following formula (2.8) is used to calculate the average transmission delay:

$$Average\_transmission\_delay = \frac{\sum_{i=0}^{n}(RTimeOfPkt_i - STimeOfPkt_i)}{\sum ReceivedPackets} \tag{2.8}$$

Where, $(RTimeOfPkt_i)$ is the reception time of the $(Packet_i)$ and $(STimeOfPkt_i)$ is the sending time of the $(Packet_i)$.

Decodable Frame Rate (DFR)

The number of decodable video frames divided by the total number of transmitted video frames in a particular EPER (Effective Packet Error Rate) is known as the Decodable Frame Rate (2.9).

$$DFR = \frac{NDF(I) + NDF(P) + NDF(B)}{\sum SendFrames} \tag{2.9}$$

Where, $NDF(I)$ is the Number of Decodable Frames I, $NDF(P)$ is the Number of Decodable Frames P and $NDF(B)$ is the Number of Decodable Frames B.

Peak Signal to Noise Ratio (PSNR)

The PSNR is defined as the ratio between a signal's maximum potential strength and the power of corrupting noise that affects the integrity of its representation, according to [48]. PSNR is defined mathematically as Mean Squared Error (MSE) [56], which quantifies the cumulative square error between the original and distortion frames (o and d), as follows (2.10):

$$MSE = \frac{1}{M*N}\sum_{m=1}^{M}\sum_{n=1}^{N}|o(m,n)-d(m,n)|^2 \tag{2.10}$$

Where $o(m,n)$ and $d(m,n)$ are the brightness pixels in position (m,n) in the frame, and $M.N$ is the frame size in pixels. PSNR is defined as the logarithmic ratio of a signal's highest value to its MSE, as follows (2.11):

$$PSNR = 10*log\frac{255^2}{MSE} \tag{2.11}$$

Table 2.2 – A few video streaming QoS metrics on the VANET.

QoS metric	Signification
Throughput	The number of bits sent per second (bits/s) is the effective number of bits transmitted per second
Jitter	The difference between the I th and (i+1) th data units' delays. (variation in delay)
Packet Loss Rate (PLR)	When comparing the number of packets transmitted from the source to the number of packets lost at the receiver vehicle, the percentage of packets lost at the receiver vehicle is calculated
Packet Delivery Ratio (PDR)	Total number of packets received divided by total number of packets sent
Receiving Data Rate	Time between the start of downloading the first part and the start of playback
End to End Delay	The time interval between the commencement of packets being sent by the source and the finish of the packets being fully received by the receiver
Overhead, Cost	Number of transmissions in total
Start-up Delay	Time between the start of downloading the first part and the start of playback
PSNR	The ratio of a signal's maximum potential strength to the power of corrupting noise, which impacts the representation's fidelity

3.2 Quality of Experience metrics (QoE)

The entire acceptability of an application or service, as judged subjectively by endusers, is characterized as the Quality of Experience (QoE). A subjective evaluation of video streaming is included in QoE [57].

Many studies have used QoE measures like Mean Opinion Score (MOS) [58], User Satisfaction Percentage (USP) [59], and others to assess video streaming quality on VANET. Basic video streaming QoE measurements in VANET are summarized in Table 2.3.

Mean Opinion Score (MOS)

MOS is commonly chosen in the QoE as a consequence of subjective tests. MOS allows subjective testing to be quantified; during subjective tests, many users are requested to assess video quality and offer a precise quantifiable value for video quality; MOS is determined by averaging all video quality values at the completion of subjective tests [58].

User Satisfaction Percentage (USP)

User Satisfaction Percentage is the percentage of time that MOS retains user satisfaction above an acceptable level; a higher value of USP indicates that the destination receives a greater number of excellent windows [59].

Structural Similarity Index Measure (SSIM)

SSIM is a video quality evaluation that separates the measurement of brightness, contrast, and structural distortion. It was created by [60] in order to quantify similarity between two pictures according to Human Visual System perception. The authors in [61] examined and studied PSNR and SSIM to have a better grasp of their similarities and differences. PSNR values may be predicted from SSIM values and vice versa, according to this study, and PSNR and SSIM differ primarily in their degree of sensitivity to image degradation types.

Table 2.3 – A few video streaming QoE metrics on the VANET.

QoE metric	Signification
MOS	The average of all subjective video quality ratings
USP	MOS is over the user satisfaction criterion a certain percentage of the time
MDP	Measurement of loss window distribution
SSIM	An objective QoE metric that measures the video's structural distortion in order to have a better match with the user's subjective perception

4 Video encoding techniques

In this section, We'll go through several video streaming encoding techniques utilized in VANET in this section.

4.1 Scalable Video Coding (SVC)

Layered coding is the foundation of Scalable Video Coding (SVC). The video stream is divided into two layers: the first is a basic layer that represents I-frames and P-frames, and the second is an enhanced layer that represents B-frames. The fundamental layer ensures the quality of the video, while the enhancement layer improves it [62].

4.2 Multiple Description Coding (MDC)

Multiple Description Coding (MDC) encodes video streaming as a collection of descriptions, each of which is a sequence of frames. If a frame of a certain kind is disturbed, the decoder will recover the frame from another description, according to MDC's redundancy recovery method [63].

4.3 Flexible Macroblock Ordering (FMO)

This method of encoding works by dividing a frame into slices, each of which contains a collection of Macro-Blocks (MBs) . The Macro-Block is a fundamental slice unit. FMO has a lot of power when it comes to error resistance. If one slice is unavailable at the decoder, for example, each lost macro-block of that slice might be surrounded by macro-blocks from other slices (above, below, right and left) [64].

4.4 XOR based coding

Because XOR based coding is efficient and simple, it is extensively employed in error resilience techniques such as Forward Error Correction (FEC) and Erasure Coding (EC). The concept behind FEC and EC is to add redundant packets to original packets in order to retrieve them later at the end receiver [65].

When the XOR logical operation is done to a group of packets (i.e. a, b,..., n) at the sender to generate one redundant packet, the existence of all of these packets at the receiver without one lost packet allows the lost packet to be recovered [65].

4.5 Network Coding (NC)

Network Coding (NC) is founded on the notion that intermediary nodes (re-encoders) combine the content of received units of data to create new units of data, allowing for a reduction in the quantity of sent units of data and therefore an improvement in wireless network throughput [66].

There are many variations of Network Coding (NC) like the Packet Level Network Coding (PLNC) uses the packet as the unit of data, whereas the Symbol Level Network Coding (SLNC) uses a collection of consecutive bits as the unit of data.

5 Video encoding standards

This section covers the most major video streaming encoding standards in VANET.

5.1 Motion Picture Expert Group (MPEG-4)

To reduce video streaming, several mobile networks employ the Motion Picture Expert Group (MPEG) video coding standard. MPEG-2, MPEG-4, MPEG-7 and MPEG-21 are only a few of the many versions of the MPEG multimedia standard that have been released [67]. In VANET, we used MPEG-4 for video streaming coding since it is the version MPEG that most multimedia apps accept and delivers good video quality on mobile networks[68].

5.2 Advanced Video Coding (H.264/AVC)

Advanced Video Coding (H.264/AVC) is a video coding standard that utilizes FMO coding methods, in which each frame may be split into up to eight slices and Macro-Blocks (MBs) can be assigned to slices in six (06) different ways [69].

5.3 High Efficiency Video Coding (H.265/HEVC)

High Efficiency Video Coding (H.265/HEVC) is a new visual compression standard that aims to cut bandwidth needs by 50% while maintaining PSNR video quality is the same as the H.264/AVC standard. H.265/HEVC, like H.264/AVC, is based on encoding the video frame into a collection of slices and recovering the lost slices using both spatial and temporal concealment methods. One of the distinctions between H.264/AVC and H.265/HEVC that makes the latter more efficient than the former is that H.264/AVC utilizes elementary frame units (i.e. Macro-Blocks) with the same and fixed size, whereas H.265/HEVC employs elementary frame units with various sizes. H.265/HEVC also has a greater number of spatial and temporal concealing methods than H.264/AVC [70].

6 Related works on video streaming on VANET

This section reviews and discusses the classification of the most major proposed video streaming projects in the VANET literature.

As illustrated in figure 2.1, VANET video streaming research are divided into three categories: video streaming works at the application and transport layers, video streaming works at the network layer, and video streaming works at the MAC layer.

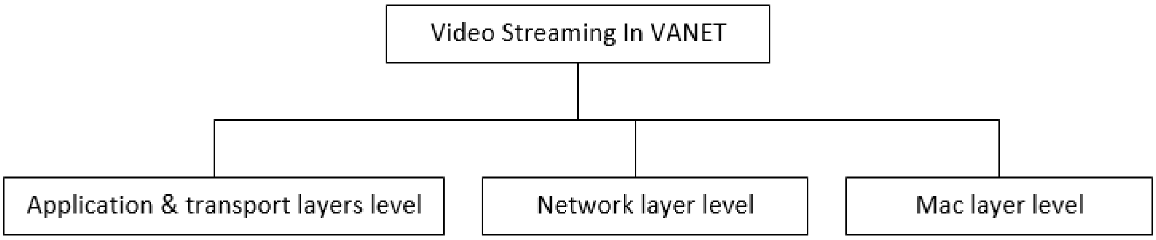


Figure 2.1 – VANET classification of video streaming works.

6.1 VANET video streaming works at application and transport layers

To increase video streaming quality in VANET, approaches in this category employ a range of video encoding and video streaming error resilience standards, processes, and techniques, primarily at the application and transport levels, as illustrated in figure 2.2.

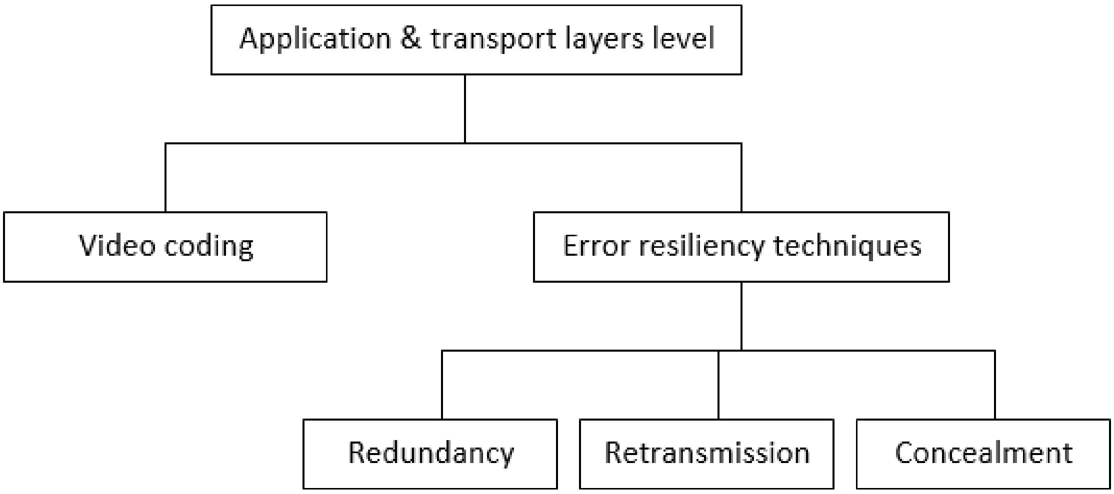


Figure 2.2 – Techniques of video streaming works in VANET at the application and transport layers.

6.1.1 Video encoding

Various video encoding works employing various standards and encoding algorithms have been proposed in the VANET video streaming literature. [71] demonstrated a VANET video transmission architecture based on the notion of peer-to-peer and using MDC and slices for video encoding. For slice compensation, this research integrates MDC's redundancy recovery method with FMO's recovery mechanism. When compared to video transmission utilizing the MDC approach, In terms of packet loss ratio, control overhead, and video PSNR, this study improves the quality of video streaming. nevertheless, the transmission delay factor was not evaluated to guarantee that no deadline time restrictions were broken.

On the other hand, several tests have demonstrated that the H.265/HEVC video encoding standard outperforms competing standards in VANET. The video coding standards H.264/AVC and H.265/HEVC were examined and compared on [72] highway VANETs. This project proved the advantage of H.265/HEVC over H.264/AVC in terms of frame loss and PSNR of VANET-transmitted video.
The compression effectiveness of existing video compression standards was assessed across an urban VANET in [73]. The trial data indicated that 265/HEVC delivers similar levels of video quality with lower bit rates than H.264/AVC and VP9 (a Google-developed video coding format). This is due to the video efficiency encoding of 265/HEVC, which lowers the bandwidth required. [74] looked examined video streaming over the VANET that was compressed utilizing the HEVC standard, as well as the issue of packet loss.

6.1.2 Error resiliency techniques

Redundancy-based techniques, retransmission-based techniques, and concealment-based techniques are the three types of video error resilience strategies classified by VANET.

6.1.2.1 Redundancy based techniques

In the VANET literature, several video streaming efforts employ redundancy-based methods (Forward Error Correction, Interleaving and Erasure Coding).

— **Forward Error Correction (FEC)**

Despite the fact that FEC-based approaches have a high redundancy rate as their primary drawback, various FEC-based video streaming over wireless networks have been proposed to overcome FEC drawbacks such as network overloading and restricted burst error recovery. Forward-Looking FEC (FL-FEC) [75], Enhanced Random Early Detection FEC (ERED-FEC) [76], Adaptive and Interleaving FEC (AIFEC) [77], and FEC with Path Interleaving (FEC-PI) [78]are a few of the methods we discuss. Packets from the same block and non-continuous packets from the preceding block can be used to recover lost packets, according to FL-FEC. This is the only approach to fix the issue of burst packet loss. The Access Point (AP) employs ERED-FEC, which dynamically adjusts the redundancy rate based on both the wireless channel state (based on the packet loss rate) as well as the volume of network traffic.AIFEC dynamically changes the redundancy rate based on video priority levels, throughput, and wireless channel condition. When video is broadcast across several routes, FEC-PI is based on the notion of employing the FEC mechanism at the video sender level. As a consequence, if any channel has a burst packet loss, the receiver may compensate by utilizing video from other paths.

In study [79], an FEC-based technique called Sub-Packet FEC (SPFEC) was introduced as an alternative to FEC in order to improve video streaming quality over wireless networks in terms of jitter and recovery performance.

— **Interleaving**

FEC with Interleaving Real Time Optimization was proposed by Bucciol et al. on [80] as an error recovery solution for video packets in VANET (FIRO). FEC is used to recover uniform mistakes, interleaving is used to recover burst errors, and reporting is used to determine the channel transmission loss ratio. The sender dynamically changes the FEC and interleaving settings based on this assessment. FIRO increases video transmission quality when compared to FEC and interleaving methods. To create more compelling results, FIRO may be tried in an urban context with limited network capacity.

Quadros et al. integrated the interleaving approach in their proposed QOE-aware and driven Receiver-based (QORE) mechanism in [81] to cope with the problem of burst losses at the application layer.

— **Erasure Coding (EC)**

Rezende et al. examined and compared EC with RLC coding and EC with XOR based coding for video transmission in the VANET in [65]. Because XOR-based coding is more resilient to lost mistakes than RLC coding, the research found that EC using XOR-based coding is more efficient in terms of delivery ratio and end-to-end latency than EC using RLC coding. It is still essential to establish the value of EC in the VANET as compared to other visual error resilience solutions.

The authors of [82] looked at the impact of video packet redundancy on video broadcasting on a highway VANET that uses a gossiping broadcasting approach to transmit video, as well as an evaluation of utilizing EC on this network. Because redundancy solves the problem of VANET connections disconnection, the simulation results showed that redundancy increases the delivery ratio of video packets. In addition, the simulation research revealed that EC has little influence on redundancy efficiency, especially for receiver cars that are far away from the video source vehicle. This is because, despite the fact that basic redundancy allows for the decoding of a part of the original packets, the original packets cannot be deciphered when the number of received packets is inadequate. The overall outcomes of this study might be compared to redundancy and EC in an urban context. This study only looked at the highway scenario, where traffic and crashes aren't as bad as they are in cities.

Erasure Coding with Realtime Transport Protocol (EC-RTP) was proposed by Mammeri et al. in [83] as a solution for the VANET's high packet loss rate issue with video streaming. This research project developed two converters to adapt RTP to VANET: the first converts RTP packets to EC-RTP packets that are transmitted across the network, and the second converts EC-RTP packets to RTP packets that are forwarded to an RTP player. EC-RTP reduces packet loss and improves

PSNR video quality as compared to RTP. Due to the high expense of genuine tests and the authors′ inability to use IEEE 802.11p technology, only a single hop was examined in this study; nevertheless, IEEE 802.11p technology and a multi-hop scenario should be explored in future EC-RTP investigations.

6.1.2.2 Retransmission based techniques

In certain VANET video streaming research, the retransmission approach is employed as a basic mechanism. In VANET [84], we discuss Xie et al., who proposed a multi-path video streaming routing. I-frames are sent over a first path based on Transmission Control Protocol (TCP) , which allows for error recovery via retransmission, while P-frames and B-frames are sent over a second way based on User Datagram Protocol (UDP) . The recommended technique offers superior video transmission quality in terms of PSNR, SSIM, and receiving data rate when compared to FEC and UDP. The work′s shortcoming is the significant transmission delay imposed by TCP′s retransmission mechanism.

In [85], Xie et al proposed a Multi-channel Error Recovery Video Streaming system (MERVS) based on the same principle as [84]. In addition, the authors employed Priority Queue, Quick Start, and Scalable Reliable Channel to reduce MERVS transmission delay (SRC). For both TCP and UDP channels, Priority Queue removes the disorder in the MAC layer′s waiting queue. Quick Start improves TCP channel throughput by reducing the negative effect of congestion management. In some instances, the SRC prevents network performance degradation. The simulation results showed that MERVS with Priority Queue, Quick Start, and SRC achieve a reduced transmission latency when compared to TCP, MERVS, MERVS with Priority Queue, and Quick Start. Furthermore, the simulation demonstrated that the suggested method produces high-quality video transmission.

6.1.2.3 Concealment based techniques

In VANET, error hiding methods are utilized in a variety of video streaming projects. Pinol et al. used the previous decoded frame to retrieve the lost frame at the decoder to create an error concealing method for video streaming transmission over VANET in [74]. Error concealment reduces bandwidth costs and transmission time by recovering lost packets without retransmission or redundancy of video packets, however it creates certain abnormalities in the presented video.

6.1.3 Comparison of several video streaming methods used in VANET at the application and transport levels

The present video streaming efforts in VANET that are planned for application and transport layers that deal with video encoding and error resilience are summarized in Table 2.4. As shown in the table, each work employs proprietary techniques to assess video streaming quality, including video encoding, error resilience, QoS / QoE measurements, forwarding type (unicast, multicast, or broadcast), effective evaluation protocol for the forwarding type, and VANET environment type.

Every error resilience technique appears to support a certain video encoding method, such as redundancy support for MDC or SVC video encoding or concealment support for slices encoding. Most works utilize the loss ratio factor as an assessment criterion since it has a direct influence on visual video quality. But a few works does not consider the transmission delay factor, This is a critical component in ensuring that the application deadline is adhered to. Most works built for a highway environment employ redundancy, which enables for remote cars to successfully receive the video for the purpose of deal due to the excessive frequency of highway link disconnections, as shown in the table.

Table 2.4: Comparison of several video streaming methods used in VANET at the application and transport levels.

Work	Video encoding	Error resiliency technique	Evaluation metrics	Forwarding type	Routing protocol	Environment
[71]	MDC and checkerboard slices in combination	Redundancy of MDC and FMO concealment	Packet loss ratio, control overhead, PSNR	Unicast	Split Multi Routing	Urban
[72]	H.264/ H.265	H.264 and H.265 error concealment	Frame loss, PSNR	Broadcast	Distance Based strategy	Highway
[74]	HEVC	Simple Error Concealment Method	Rate Distortion, PSNR	N/A (Not/ Available)	N/A	Urban
FIRO [80]	H.264/ AVC	FEC, Interleaving	Packet Loss Rate, PSNR	N/A	N/A	Highway
[65]	H.264/ MPEG-4 AVC	EC	Delivery ratio, delay	Unicast	VIRTUS	Highway
[82]	MPEG	EC	Correctness (received packets percentage), overhead	Broadcast	Gossiping	Highway

MERVS [85]	H.264/ MPEG-4	Retransmission mechanism of TCP	PSNR, SSIM, total time to transmit the video, receiving data rate	N/A	AODV	Urban
ECRTP [83]	H.264	EC	Packet loss rates, delay, PSNR, SSIM, bandwidth usage	N/A	N/A	N/A
QORE [81]	MPEG-4	Interleaving	Reachability, PDR, Average Delay, SSIM, MOS are all terms that refer to the ratio of forwarding nodes to receiving nodes	Broadcast	N/A	Urban and Highway
[73]	H.265/ HEVC, H.264/AVC and Google VP9	N/A	Frame Delivery Ratio, PSNR, MOS	N/A	N/A	Urban

6.1.4 Discussion of video streaming at the application and transport levels: Advantages and disadvantages

This branch of research employs video encoding and error resilience techniques to improve video streaming transmission quality. Layer coding, MDC coding, FMO coding, and other video encoding techniques were investigated. When utilizing error resilience approaches, the aim of the encoding video is to make error recovery easier. For example, network overload and transmission delay are reduced when Network Coding with Redundancy is used, while video encoding reduces the negative impact of fault resilience methods.

The three primary techniques utilized to recover consistency and burst faults of video packets in VANET are redundancy, retransmission, and error hiding. In terms of network overhead and transmission latency, Table 2.5 provides a comparison of several error resilience techniques in VANET. The network overload is significant in the case of redundancy methods such as FEC, EC, and interleaving and owing to redundant packets, but the transmission latency is large in the case of retransmission technique because a receiver request is required for duplicate video packets. The receiver is subjected to the error concealing approach without any extra network stress or transmission delay.

Table 2.5 – A comparison of error resilience methods for video streaming on VANET.

Error resiliency technique	**Network overload**	**Transmission delay**	**Artifacts in the displayed video**
FEC	High	Low	Low
Retransmission	Low	High	Low
Erasure Coding	High	Low	Low
Interleaving	High	Low	Low
Error concealment	Low	Low	High

6.2 VANET video streaming works at the network layer

The relays on the vehicle selection strategy for video streaming in VANET, is in charge of determining The most dependable path(s) for video streaming quality optimisation between the source and destination nodes at the network layer level. Traditional based schemes, forwarding based schemes, and cluster based schemes are the three types of video streaming methods used in VANET at the network layer. In VANET, there are three types of video forwarding strategies: unicast, multicast, and broadcast. Video broadcasting is the dispersion of the video to all cars in the network. Unicast video streaming is based on the notion that the video is triggered to one destination,Multicast video streaming, on the other hand, is based on the concept of triggering the video to many locations.

6.2.1 Traditional schemes

Traditional video unicasting/multicasting methods include topology-based (proactive, reactive) and geographic-based (unicasting/multicasting) routing protocols. Xu et al. introduced the VANET-EvalVid framework in their paper [86], which comprises of three Tools that are integrated: ns-2 [87], Evalvid [88], and VanetMobiSim [89], to compare three routing methods for video streaming on VANET: Destination-Sequenced Distance-Vector Routing (DSDV) [90], Ad hoc On Demand Distance Vector (AODV) [91], and Greedy Perimeter Stateless Routing (GPSR) [92] under various environmental circumstances. Because the control messages in GPSR are decreased, In terms of frame loss rate and video PSNR, it is more suited for video transmission through VANET than the proactive routing protocol DSDV and the reactive routing protocol AODV. GPSR, on the other hand, does not offer exact vehicle locations, which might affect video

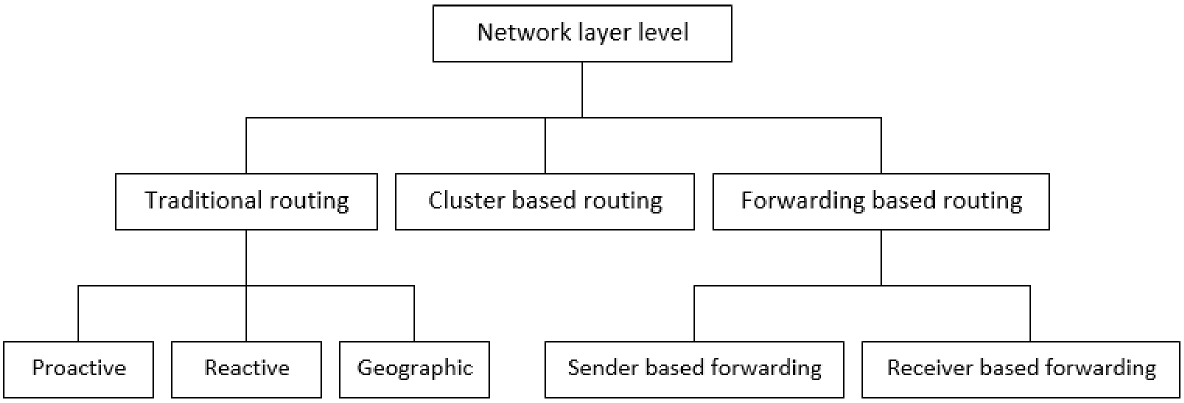


Figure 2.3 – In a VANET, video streaming techniques work at the network layer.

transmission in a genuine VANET. As a result, a number of research have combined topology-based and geographic-based methods. Zaimi et al. investigated different video streaming routing techniques in VANET in [93] and [94]. The routing protocols were evaluated in terms of QoS and QoE metrics in the same environment and under the same conditions in order to offer a quantitative and qualitative comparison between them. The simulation findings show that reactive routing protocols (AODV, DSR, and DYMOUM) are superior than proactive routing protocols (DSDV, OLSR, and FSR) and hybrid routing protocols (ZRP). The results also showed that while position-based routing protocols (GPSR, VADD, and HLAR) give reduced latency and overload, they also provide poorer Packet Deliver Ratio (PDR) and throughput, affecting PSNR, SSIM, and MOS video quality due to location accuracy issues. Other upgraded geographic protocols for video streaming in VANET can be evaluated to improve this work. The number of video streams and the environment buildings can impact the throughput, latency, and jitter of video transmission in an urban VANET based on Optimized Link State Routing (OLSR) [96], which is considered a proactive routing system, as Honda et al. demonstrated in [95]. This study should demonstrate the performance of OLSR in comparison to other routing protocols such as AODV, DSDV, and GPSR. Furthermore, video quality evaluation metrics such as PSNR and SSIM are not taken into account in this study. In [97] Zaimi et al. proposed a Greedy Perimeter Stateless Routing protocol with two Paths (GPSR-2P) for video transmission in an urban VANET. The GPSR video routing technology was used over two routes to prevent congestion. To determine the shortest path from the sender to the destination, each sender car transmits the video packets to its geographically nearest neighbor to the destination under the GPSR protocol. In comparison to GPSR, the simulation results showed that GPSR-2P has a greater packet delivery ratio and a reduced transmission latency. Furthermore, this concept enhances the user's experience. However, for each advancing vehicle in our investigation, only two neighbors were evaluated. GPSR-2P should be tested in a large number of neighbors to generalize the findings (K-neighbors). To address the video streaming issue in VANET, a number of improvements to the topology-based routing protocol have been proposed. To address the routes' instability concerns, Moussaoui et al. developed an Enhanced version of the AODV protocol (En-AODV) in [98]. En-AODV chooses the best stable path by using cross-layer information regarding connection quality, link lifespan estimation, and destination area data. In comparison to AODV, simulation findings show that En-AODV achieves a greater Packet Delivery Ratio (PDR), a lower average end-to-end latency, and reduced network overhead. In [59] Pham et al. developed a QoE-based routing system for video streaming over VANETs (QOV), which is a modification of OLSR that balances transmissions over lower-loss routes. QOV outperforms OLSR in terms of QoE metrics like MOS, USP, MDP, and packet loss rate, but it suffers from the same bandwidth overhead issue as OLSR owing to the VANET's periodic control message exchange and dynamic topology. Walker and Radenkovic updated the GPSR routing protocol in [99] by adding the TArgeted Remote Surveillance module (TARS) to create the GPSR-TARS protocol. Cars with numerous receivers can use GPSR-TARS to request and receive video from vehicles within a defined surveillance zone. In order to manage the congestion problem, GPSR-TARS uses a congestion sensitive clustering technique that dynamically changes the size of the monitoring zone. Due to their limitations in detecting and handling congestion, the simulation results showed that GPSR-TARS outperforms the standard routing protocols GPSR, AODV, and DSDV. Quadros et al. proposed MVIDE (Multiflow-driven VIdeo DElivery) for video packet distribution on VANET via efficient routes in [100]. This paper also suggests combining MVIDE with GPSR with Movement Awareness (GPSR-MA) [101] in order to improve transmitted video in terms of QoS and QoE metrics, while taking into account specific routes, vehicle mobility, and application restrictions.

6.2.2 Forwarding-based schemes

Sender Based Forwarding (SBF) and Receiver Based Forwarding (RBF) are the two types of video streaming forwarding-based techniques utilized in VANET. The Sender Based Forwarding and Receiver Based Forwarding methods use geographic information to identify relay vehicles for a multi-hop video broadcast in VANET. in [102] investigated and compared the two video forwarding methods SBF and RBF in a highway environment utilizing VANET. Because SBF contains a greater number of control messages than RBF, the authors discovered that RBF delivers superior video quality in terms of PSNR. The lack of a transmission delay factor in the comparison of SBF and RBF is a drawback of this work.

6.2.2.1 Sender-Based Forwarding schemes (SBF)

Each vehicle in the SBF sends control messages to its neighbors on a regular basis. The control message contains vehicle-specific information such as the vehicle's position, speed, and direction. When a vehicle receives a control message, the list of nearby vehicles is updated. Based on this information, the forwarder selects the next forwarder vehicle from among its neighbors. One of the factors considered in the choice is the distance to the end recipient. The issue with SBF is that control information is not always available, particularly in the case of disconnection. Furthermore, the transmission of this control message might raise network overhead.

For video streaming over the VANET, Bradai et al suggested a Selective Rebroadcast Mechanism (ReViV) for video streaming broadcasting through VANET in [103].

With the objective of reducing interference, ReViV is based on the IEEE 1609.4 protocol [104] with the inclusion of a module for selecting video forwarding vehicles based on SBF and their dissemination capabilities. The simulation revealed that ReViV improves quality of video streaming for frame loss, latency, and PSNR of received video when compared to IEEE 1609.4.

6.2.2.2 Receiver-Based Forwarding schemes (RBF)

The sender vehicle in RBF transmits its packets to its neighbors. Each neighboring car estimates its own waiting time based on parameters such as the distance to the destination. Among the neighboring cars, the highest priority vehicle chosen as next hop has the least wait time. Following the computation of the waiting time, each neighboring car begins to reduce its waiting time while listening to the communication assistance. During the waiting period, the adjacent vehicle notices a packet transmission in the channel, it cancels its transmission. When the adjacent vehicle's waiting time expires, it forwards the received packets. As a result, the RBF method is founded on the concept that neighboring cars, not the sender vehicle, choose the next forwarding vehicle. Because of the waiting period, there is an extra transmission delay imposed while selecting forwarding cars is RBF's limit.

Several papers have suggested video packet distribution on VANET using RBF for unicasting or multicasting forwarding. The REceiver-based solution with video transmission DECoupled from relay node selection (REDEC) [105] modifies RBF by including the stability factor in the waiting time calculation and taking into account the concept of a waiting window. This is intended to decrease the extra transmission delay caused by relay trucks being chosen based on their waiting durations. The waiting window is a period of time during which a node delivers packets before selecting a relay vehicle. Another RBF technique is the Video Reactive Tracking-based UnicaSt protocol (VIRTUS) [106], which distributes video packets depending on approximated position information. The reader may find [107] in this category, which is a VIRTUS with Decoupled from Video Transmission Density-Aware Relay Node Selection (DADVT). The authors of this study presented a waiting time calculation based on two factors: the distance to the destination and the density of the network in terms of cars. A QOe-Driven and LInk-qualiTy rEceiver (QOALITE) [108] is another RBF-based approach that estimates the waiting time based on location information, link quality, and QoE. Due to the use of a multi-criteria selection of relay vehicles such as QoE, which is critical in the human evaluation of video transmission, the authors of [108] give the most dependable way compared to those proposed in [105] and [106].

6.2.2.3 Cluster based schemes

Various VANETs papers have advocated video distribution following the formation of network clusters. The goal is to make the routing procedure easier while also improving transmission quality. In [109], Tal and Muntean suggested a VANET-based user-oriented and cluster-based multimedia distribution solution. To offer multimedia material, clusters are generated based on passengers and their profiles implementing the Quality-Oriented Adaptive Scheme (QOAS) [110]. The simulation demonstrated the usefulness of this scheme In terms of mean cluster head longevity, average throughput, and loss, this approach is superior. when compared to Lowest-ID, the most widely used clustering algorithm in VANET [111]. This method can choose the best Cluster Head with a life-time longer than Lowest-ID. The transmission delay factor was not included in the evaluation of this work's effectiveness. In [112], they proposed a Cluster and Dynamic Overlay-based video distribution over VANETs (CDOV) that is divided into two parts: the first is VANET clustering, which consists of cluster head vehicles and cluster members interested in the same video. The second component is a Dynamic Overlay-based Video Delivery Scheme that provides and constructs an overlay tree utilizing control messages to facilitate video sharing across cluster members. In comparison to non-cooperative communication and gossiping-based communication, the simulation showed that CDOV delivers better video transmission in terms of start-up latency and packet delivery rate. Furthermore, CDOV enables instantaneous video distribution to the requester car through overlay tree, reducing start-up time. Furthermore, when a video is requested, CDOV chooses the optimal vehicle with video portions that have a higher packet delivery rate. CDOV has a significant control cost due to the large amount of control messages required to ensure clustering and create the overlay tree.

6.2.3 Comparison of several video streaming methods used in VANET at network layer

In general, VANET video streaming methods at the network layer choose cooperative relays (vehicles) with the objective of disseminating video data while maintaining good video transmission quality. Each system employs a video encoding standard as well as certain QoS and/or QoE measures to determine video quality. In addition, each article chooses a VANET setting (urban or highway) in order to conduct their research. Each work also uses a routing method (traditional, SBF, RBF, or cluster-based) to send video along one or more pathways. The works in this category for unicast, multicast, and broadcast video streaming are listed in Table 2.6.

Table 2.6: Comparison of several video streaming methods used in VANET at network layer.

Work	Video encoding	Evaluation metrics	Video forwarding	Routing based approach	Environment
VANET EvalVid [86]	MPEG-4	Frame loss rate, PSNR	Single	Traditional routing (DSDV, AODV, GPSR)	N/A
[95]	N/A	Jitter, delay, and throughput	Single	Traditional routing (OLSR)	Urban
[102]	MPEG4	PSNR	Single	SBF, RBF	Highway

REDEC [105]	H.264/ MPEG-4 AVC	Delivery ratio, PSNR,video reception rate, endto-end delay, number of transmissions, jitter.	Single	RBF	Urban
VIRTUS [106]	MPEG	delay, cost Frame, loss	Single	RBF	Highway
DADVT [107]	H.264/ MPEG-4 AVC	Delivery ratio, PSNR,end-to-end delay, number of transmissions, video receiving rate	Single	RBF	N/A
GPSR-2P [97]	MPEG-4	PDR, delay, PSNR,VQM, SSIM	Multi	Traditional routing (GPSR)	Urban
En-AODV [98]	N/A	Packet Delivery Ratio,end-to-end delay,number of RREQs broadcasted in the network	Single	Traditional routing (AODV)	Urban
GPSR-TARS [99]	N/A	PDR, delay	Single	Traditional routing (GPSR)	Urban
ReViV [103]	N/A	Frames loss, frames delay, PSNR	broadcasting	SBF	Urban

6.2.4 Discussion of video streaming at the at network level: Advantages and disadvantages

Choosing the best relay vehicles, in a multihop communication mode, forwards the received video packets, video streaming operations at the network layer in VANET tend to enhance video streaming quality in terms of QoS and/or QoE measures at the network level. The three types of video distribution schemes are cluster-based schemes, traditional schemes, and forwarding-based schemes we have categorised. The conventional VANET video distribution methods are based on the MANET video dissemination schemes. In contrast to this, the topology of a VANET is very dynamic. As a result, VANET necessitates a unique routing strategy. The sender is in charge of choosing the next forwarder vehicle for the packets in SBF. However, due to the large amount of control messages exchanged between the vehicles, SBF suffers from a high level of bandwidth overhead and collisions. The receiver is in charge of forwarding video packets in RBF. This sort of forwarding scheme has a significant latency due to the time it takes for intermediate vehicles to become relays, but the network overhead in RBF is smaller than in SBF. Some methods based on video packets forwarding over a single path fall into this category, and the transmission suffers from a high level of congestion collisions. To address the latter issue, numerous recent studies have recommended forwarding video streams via various routes in order to improve video packet transmission reliability and reduce communication congestion. Other techniques offer network clustering to help with video distribution; however, cluster-based schemes suffer from network congestion owing to the large number of control messages sent to establish the clusters.

6.3 VANET video streaming works at the MAC layer

To increase video streaming quality in VANET, The works in this group change the MAC layer's video transmission settings, such as the size of the contention window and resource allocation mechanism. In [113], Asefi et al. proposed a MAC layer adaptation of IEEE 802.11p [20]. The proposed adaptive approach employed multi-objective optimization to reduce the amount of video frame retransmissions in the VANET while also reducing the likelihood of playback freezes and video startup at the destination vehicle. The researchers demonstrated that, as compared to IEEE 802.11p,While taking into account real transmission channel and environment restrictions, the proposed adaptation enhances video transmission quality at the receiver vehicle in terms of playback freezes. The additional transmission start-up time may result in the user missing their deadline.

Ruijian et al. [114] proposed a novel method called Resource Allocation and Layer Selection with Base Layer Guarantee to tackle the problem of playback freeze of video streaming over highways (RALSB). Base layer Guarantee (BG) and Resource allocation and SVC layer selection (RS) are the two steps of RALSB. In the BG phase, a simple yet effective approach for solving the base layer guarantee problem and ensuring smooth video playing is presented. In the RS phase, greedy and Dynamic Programming (DP) algorithms are used to address the MAC layer resource allocation problem and the SVC layer selection problem. RALSB can minimize playback freeze, but it can't give greater PSNR video quality, according to the findings of the trial. In [115], Belyaev et al. demonstrated that using Skype application [116] for video transmission from vehicles to infrastructure suffers from a significant rate of packet losses, lowering visual video quality. The major reason of this issue is a lack of coordination amongst vehicle users for channel resource allocation at the MAC layer when they simultaneously upload video data, resulting in network congestion. This research found that in order to optimize bandwidth distribution, users must coordinate on a fundamental level.

6.3.1 Comparison of several video streaming methods used in VANET at MAC layer

By changing the MAC layer's transmission settings, this category aims to improve the quality of video transmission in VANET. Table 2.7 lists the works that have been reviewed. As seen in the table below, The modification might be used to improve the resource allocation technique or update the video frame retransmission limit based on network conditions.

Table 2.7: Comparison of several video streaming methods used in VANET at MAC layer.

Work	**Video encoding**	**Evaluation metrics**	**Adaptive parameters**	**Routing protocol**	**Environment**
[113]	N/A	frequency of playback freezes, start-up delay	Retransmission limit	Greedy geographic routing	Urban
[114]	SVC	SVC layer distributions, Average PSNR, freeze GOP number	Resource allocation	N/A	Highway
[115]	H.264/ AVC	PSNR, Uplink bit rate	Resource allocation	N/A	N/A

6.3.2 Discussion of video streaming at the MAC level: Advantages and disadvantages

By changing parameters like contention window size and resource allocation strategy, this category enhances video streaming quality. A few papers in the literature employ intelligent techniques and systems,such as optimization heuristics or neural networks, to carry out this modification, these strategies yield ideal values for changeable parameters.

7 Focused topic of VANET And Vehicular Fog computing

Table 2.8 – Focused areas of routing data in existing surveys in VANET and fog computing.

Focused topic of VANET And Vehicular Fog computing	**Description**
The CRPV [117]	Fog computing must be used to provide dependable content delivery, scalability, and video-stream quality while delivering multimedia broadcasts via VANETs.
Migration mechanisms Virtual Machine VM [118]	This technology to improve the use of intensive physical resources. In the new paradigm of vehiclar fog networks, vehicle mobility is a major challenge for the continuity of services in the cloud, this mechanism adress this problem by configure an environment For lack of pressure on physical resources.
Real-time interactions between cloud and fog [119]	Vehicles may now receive and upload data from a roadside communications infrastructure using V2I communication, which enhances collaboration across access technologies such as cloud computing and fog computing.
The SRB protocol [120]	Protocol utilizes vehicle behavior in an ad hoc network partition to discover vehicle clusters automatically utilizing zones of interest. Only opportunistically selected cars, known as CHs, are routed packets.
Video croudsourcing for vehicular fog computing [121]	Discuss the difficulties of integrating vehicular fog computing for real-time analytics of crowdsourced dash camera footage across all nodes and the ability to stream any video event.

Conclusion

Basic video streaming issues such as video evaluation measures, video encoding techniques, and video compression standards are covered in this chapter. This chapter also featured a complete state-of-the-art evaluation of various video streaming works over VANET, including categorization, research, and comparison of these various works in terms of various transmission metrics to assure high video streaming quality.

The next chapter, a conceptual view of our simulation model will be proposed and a study scenario with the implementation of the different algorithms.

Chapter 3

Vehicular Fog Nodes For Traffic Video Streaming

Introduction

In the preceding chapter, we discussed the current state of the art for video streaming information dissemination in vehicular networks and fog computing environments. It is technology in the light of several converging trends which are expressed by strict quality of services (Qos) and quality of experience (QoE).

To improve road efficiency by enhancing traffic safety and functioning as a service facilitator for passengers, drivers, and public safety officers, such as capturing some traffic situations or any event that occurs on the road, such as accidents or traffic congestion. Also, enhancing the comfort applications in the vehicle by running some applications smoothly in the vehicle to serve and enhance passenger comfort, such as watching movies or playing online games on long trips, and listening to podcasts or music, can improve road efficiency. From this point we aim to show the major importance of Vehicular Fog Computing applications, specifically video streaming, in improving road efficiency. Recent improvements in routing protocols and typologies for video streaming have helped improve the scalability, reliability, and quality of the information sharing experience.

In this chapter, we will propose a system that controls video streaming traffic in order to improve vehicular network performance in a vehicle fog network by integrating an approach of clustering . In particular, we proposed an algorithm which is based on the dominated set algorithm to create a cluster of virtual nodes. This virtual cluster enables video data to be broadcast in real-time with low latency and high quality.

1 Objective

The goal is to demonstrate the viability of fog computing in the domain of vehicle video streaming with the rise of self-driving vehicles. Due to latency issues seen with excessive internet traffic, the cloud fails to address these options. Fog computing appears to be the greatest choice for improving video streaming speeds.

Fog computing uses fog nodes, which are intermediary devices that bring the cloud closer to the user. It does not wish to replace the cloud, but rather to enhance it by allowing for faster data upload and download. This chapter looks at two algorithms that could be used in conjunction with vehicles and video streaming. This is represented graphically after being simulated using an Omnet++ application scenario.

2 Motivation

Today, there is a very large amount of useful information to inform drivers when an event occurs (accidents, traffic jams, roadworks, braking , available parking spaces, presence of police radar, emergency response vehicles). These events can be observed directly and in real time by the vehicle. It is also interesting that all this data is shared between vehicles in "collaborative conduct" and the like is saved.

During the interval between event occurrences, traffic events represent a significant difficulty for public safety officers. Aid vehicular ad hoc networks (VANETs) were created to deal with these problems by communicating emergency conditions. Context messages, on the other hand, do not provide enough information about the incident to allow emergency responders to use the appropriate tools. Vehicles with cameras can transmit video footage to public safety agencies, cutting rescue time. However, quality of experience (QoE) is required for these video streams in order to offer the user with a minimum level of expertise and a better view of the contents

Applications for vehicles The difficulty of meeting the needs of both communication and computation are increasing. Several vehicle applications and services will stay in the concept phase and will be unable to be implemented in daily life without powerful communication and computational support.As a result, we consider using vehicles as a communication and computation infrastructure, which we call vehicular fog computing (VFC). VFC is an architecture that establishes communication and does computation using a collaborative multiplicity of end-user clients or near-user edge devices based on the exploitation of each vehicle's own communication and computing capacities. Given the technical advances and economic advantages of integrated architectures and cloud computing, we believe that the realization of a real-time cloud, dubbed a fog, that efficiently and flexibly provides reliable electronic services with temporal guarantees onboard a vehicle is the next logical step in the development of an automotive electronic architecture.

Vehicle to vehicle communications were first introduced to provide context-aware information, such as velocity, direction, and emergency braking, to automobiles equipped with the necessary technology. Cars now include numerous cameras, sensors of various types, such as sonar and light detection and ranging (LIDAR) sensors, and actuators for driving assistance and stability control, thanks to advancements in technology. By keeping real-time maps of roadway conditions, all data collected by these sensors can improve overall automobile mobility. Furthermore, with more useful information provided by the cars, public service agencies may better control traffic situations, aiding not only other ordinary vehicles but also ambulances, police, and fire trucks.

3 Our model

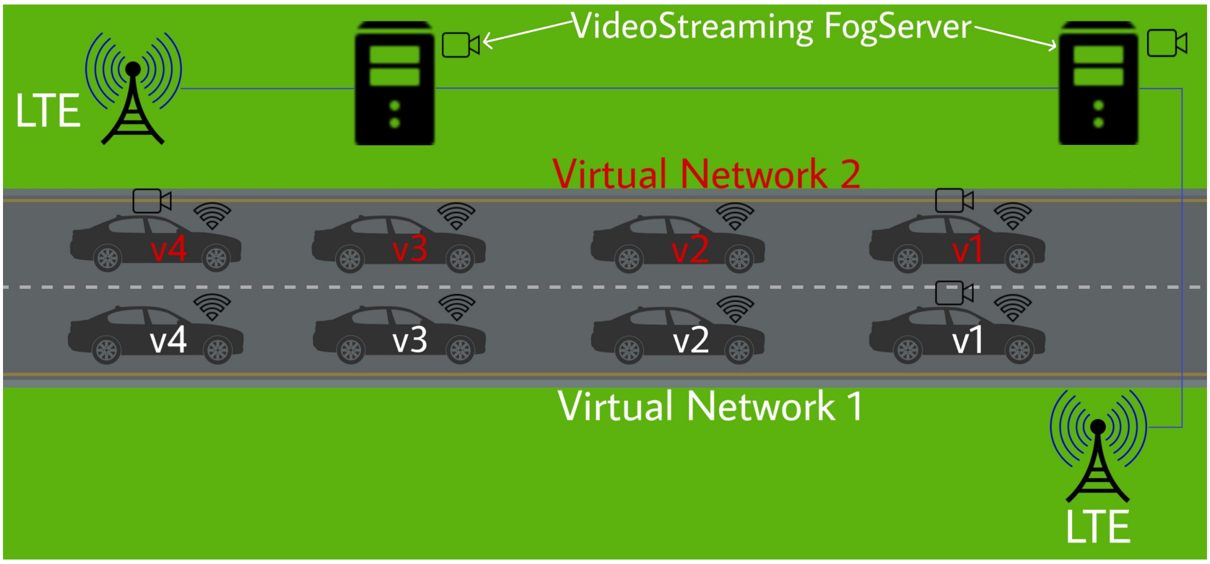


Figure 3.1 – Video Streaming in vehicular fog computing architecture.

Figure 3.1 depicts a typical VANET in which all cars have both an LTE (V2I communications) and a Wi-Fi interface (V2V communications). Following an event in lane 2, v1 of virtual network 2 , which occupies lane 2, records the moment of the event (an explosion) and shares the broadcast video with its neighbors within its coverage area (v1 of virtual network 1 and v2 of virtual network 2). Upon receiving the video, (v1 of virtual network 1 and v2 of virtual network 2) also share it. Vehicle v2 of virtual network 2 forwards the video to another vehicles in the VANET (v2 of virtual network 1 and v3 of virtual network 2). Moreover, given the communication capabilities of v1 of virtual network 1, which also has an LTE interface,By Fog Server, v1 of virtual network 1 forwards the feed to v4 of virtual network 2, It is still a long way from the event venue and so receives the event footage ahead of time

Figure 3.2 shows The flowchart of our model :

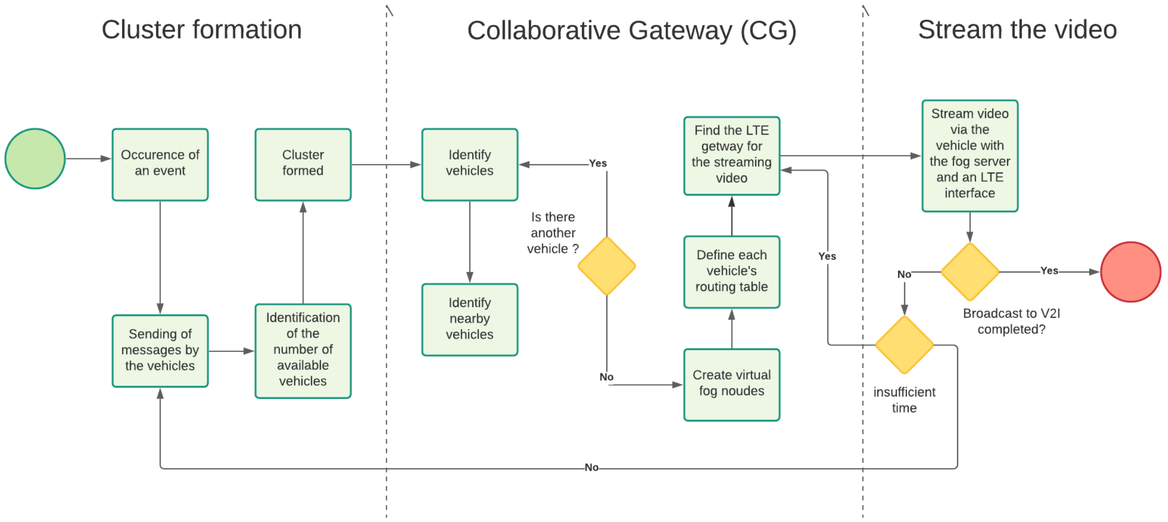


Figure 3.2 – Flowchart of our model.

Content delivery reliability, scalability, and video stream quality are all required to properly deliver video broadcasts via VANETs. The proposed architecture is as follows: Each vehicle in the V2V communication cluster has its own routing table that is defined based on the cluster's joint collaboration to reduce unnecessary data exchange during V2V communication. In most multimedia VANET applications, It is not necessary for all vehicles in a cluster to share the same live video stream, in this scenario, duplicate data would likely be transmitted, reducing network performance. As a result, when events are identified, this system is designed to select the optimum virtual fog nodes for distributing video data in real time. To help public safety agents, video data is transmitted to fixed users outside the VANET, such as police headquarters or other cars with a superior network interface at the moment. Paramedics in ambulances, for example, can utilize this information to plan to give care before they even reach at the accident scene. RSUs and LTE are two examples.

Identifying the number of vehicles accessible for clustering once an event is recognized by the vehicle camera sensor. Each vehicle should already be as calculated during cluster construction, as it will be utilized to form the routing table in each vehicle. The information communicated between each vehicle during cluster creation is used to create a dynamic routing table. The Dominant set is capable of solving complicated routing issues more quickly and effectively. The cluster head is in charge of a cluster with several alternative routes to a destination, and they may still switch to an alternate route if the primary route becomes unavailable, as well as decide which route is an alternate to the destination. Finally, the transmission of video from the vehicle to a V2I network is performed.

This procedure can be divided into the following steps:

1. The first step is to determine the number of vehicles that will make up cluster.
2. The calculation and creation of virtual fog nodes is the second phase.
3. Finally, the video from the vehicles is sent to an LTE network or a fog server V2I communication system in the third phase.

Figure 3.3 shows the architecture for Video Streaming for our model :

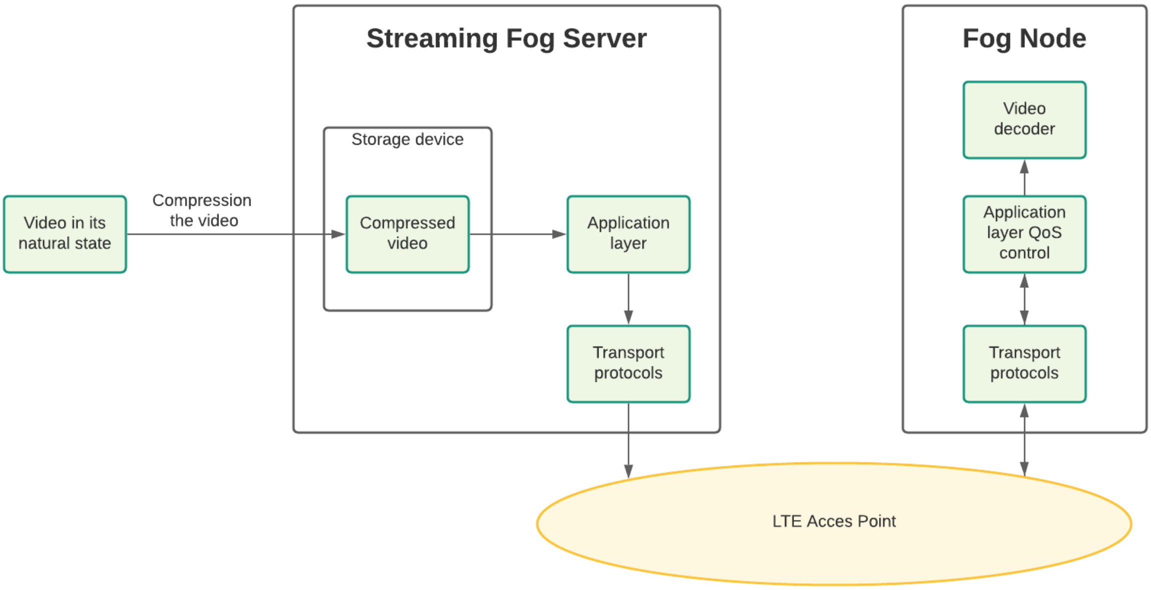


Figure 3.3 – Architecture for Video Streaming for our model.

4 Scenario

In a VANET network, disseminating traffic information, particularly video streaming, is a critical issue. This topic has been the subject of several projects and research. Researchers have proposed using vehicle video data for parking space detection, traffic monitoring, and aided driving, among other things. A reliable and high-speed network is also necessary for the comfort applications, such as watching auto network videos broadcast over the Internet. However, achieving this level of speed comes at a significant cost.

Due to the significant delay imposed by the round-trip between vehicles and the cloud, transferring data to the cloud for processing is not practical for many applications that require real-time analysis of high-resolution video feeds. In the meanwhile, just a few vehicles today have enough processing capacity to do advanced video analysis locally.

In the literature, many vehicular fog computing (VFC) architectures that contain vehicular cloudlets (i.e. cloudlets carried by vehicles) have been suggested. proposed turning vehicles into cloudlets, particularly slow-moving and parked vehicles, and forming a small cloud called JamCloud by combining computing resources from adjacent vehicles. proposed converting every vehicle into a cloudlet or virtual network with significant processing and storage capabilities for processing local sensor data, and sharing the processing results with the zone cloudlet in each coverage zone.

In our model, vehicles with predictable driving routes are turned into vehicular fog nodes, and are utilized as resources of communication and computation in terms of fog computing for vehicular applications. These vehicular fog nodes, collaborating with the computing nodes co-located with cellular base stations such as LTE access points and RSUs, serve the vehicles within range for single-hop communication and multi-hop communication. Furthermore, because of the mobility of cars, service from vehicular fog nodes may be dynamically controlled and sent on demand, reducing resource over-subscription.

The model of our project works as follows :

1. First LTE access point and vehicles exchange messages of type (beacon, ProbResp, wlan-ack, auth) in the procedure of beaconing and authentication.

2. In the second phase, the vehicles are sent to LTE access point Association request (Assoc). In this situation, the LTE responds with OK (AssocResp-OK).

3. Third phase The vehicle who needs to stream video sends to close vehicles and LTE access-point a message of type video stream request (VideoStrmReq) then it forwards it to the fog server. After that it sends video streaming packets to LTE and broadcast video data to all vehicles using udp client/server application.

Figure 3.4 shows the cluster architecture :

Figure 3.4 – Cluster architecture.

5 Algorithms

In this section we try to use the cluster technique in order to predict the groups of vehicles that share the same video traffic or those which form intermittent networks. After the formation of the clusters, it is necessary to choose the dominant sets via the application of a "Dominant algorithm" to create virtual vehicle networks. The "dominant groups" save video and perform calculation tasks. The connection between dominant ensemble members produces a "virtual cluster" where each node of this cluster takes one function among the cloud functions, for example (a storage node, calculation node, etc.).

5.1 Dominant set algorithm

Algorithm 1 Dominant set

```
Input:
    int $i$,$j$;
    $vis$[100000] boolean;
    $graph$ table[table[int]];
Output: $S$
    table(int)solve_dominant(int $fog\_node$,int $edge$)
Begin
table(int) $S$;
    for $i = 0 \quad i++ \quad i \leq fog\_node$ do
        if $vis[i] = false$ then
            $S = S + i$;
            $vis[i] = true$;
            for $j = 0 \quad j++ \quad j = lenghth.graph[i]$ do
                if $vis[graph[i][j]] = false$ then
                    $vis[graph[[i][j]] = true$;
                end if
                $j = j + 1$;
            end for
        end if
        $i = i + 1$;
    end for
    return $S$
End
```

5.2 Intermittent Sets algorithm

Algorithm 2 Intermittent set

```
table[container[int,int]]**splliter**(arcs[container[int,int]])
Begin
int $v1, v2, NbNetworks = 0, com = 0;$
$ListNet$[container[int,int]]
$itr, itr2, it$ container iterator[int,int]
$NetVec$ table[container[int,int]]
boolean $exist$=false
ListNet=arcs
    while  ListNet.lenghth<> $0$ do
        $com = 0$
        $subNet$ [container[int,int]
        $NbNetworks++$
        for $itr$=ListNet.$First$   $itr++$   $itr \geq$ ListNet.$end$ do
            $v1$=itr.First
            $v2$=itr.Second
            if $com == 0$ then
                subNet.add($v1, v2$)
                ListNet.delete($itr$)
                $com++$
            else
                for $it$=SubNet.First   $it++$   $itr \geq$ subNet.end do
                    if $(it.First = v1) or (it.Second = v2) or (it.First = v2) or (it.Second = v1)$ then
                        $exist$=true
                        if $exist == true$ then
                            subNet.add($v1, v2$)
                            ListNet.Delete($itr$)
                        end if
                    end if
                end for
            end if
        end for
        $itr++$
    end while
    for $itr2$=subNet.First   $itr++$   $itr \geq$ subNet.end  do
        NetVec.add(subNet)
    end for
    return $NetVec$
End
```

Conclusion

In this chapter, we have proposed a system that controls video streaming traffic in order to improve vehicular network performance in a vehicle fog network by integrating an approach of clustering. In particular, we proposed an algorithm which is based on the dominated set algorithm to create a cluster of virtual nodes. This virtual cluster enables video data to be broadcast efficiently, taking into account intermittent networks and rapid changes in topology. Then, we propose an application based on the Client/Server architecture to implement this mechanism.

The implementation of the different algorithms and functions, as well as the module Cluster Control and video streaming application utilizing omnet++, will be shown in the next chapter. The results of the scenario are then described, and finally, the simulation statistics are extracted.

Chapter 4

Implementation And Simulation

Introduction

The proposed approach was presented in the preceding chapter, which included its characteristics, communication techniques, algorithms, and cluster technique.

In this chapter, we will highlight the simulation of the proposition as well as the implementation of video streaming application in vehicular fog network. And describing a specific scenario for video streaming. Then we will discuss the obtained results.

1 Simulation Environments

1.1 The OMNET ++ Simulator

OMNET is a component-based, extendable, and modular C simulation toolkit and infrastructure that incorporates a graphical runtime environment and integrated development. Model frameworks designed as project independent give domain-specific features (support for simulation of communication networks, queuing networks, performance evaluation, and so on). Real-time simulation, network emulation, support for alternative programming languages (Java, C#), database integration, and a variety of additional features are available as extensions [122].

1.2 The conception of OMNET ++

OMNeT ++ was created with large-scale network modeling in mind. The following are the key design criteria as a result of this goal:

- Make large-scale simulation possible. Prioritize simulation models and turn as many of them into reusable components as feasible [123].
- To minimize the amount of effort spent troubleshooting simulation models, simulation software should make it simpler to visualize and debug simulation models [123].

- The simulation software should be flexible, adaptable, and allow simulations to be integrated into bigger applications like network planning software [123].
- Open data interfaces are required. With generally accessible software tools, it should be feasible to produce and process input and output files [123].
- Create an integrated development environment that makes model development and analysis much easier [123].

1.3 Simulation platforms

INET

The INET Framework is an open source model library for the OMNET ++ simulation environment. For academics and students working with communication networks, it includes protocols, agents, and other models. INET comes extremely handy for creating and validating new protocols, as well as when experimenting with novel or unusual circumstances. Among the benefits of the INET platform are the services it provides for automotive network initiatives [124]:

- The positioning and mobility of the nodes are important in the simulation scenarios of vehicular networks. In INET, mobility is added to nodes as modules representing mobility patterns, such as linear motion or a random waypoint. A large number of mobility models have been supplied with INET and can also be combined to achieve more complex movements [124].
- The topography has a significant impact on signal propagation in inter-vehicle simulations. Vehicles on each side of a mountain, for example, cannot communicate directly with one another. The INET platform provides a ground model to characterize the land's 3D surface for this purpose [124].

Several platforms are developed in OMNET ++, for example CASTALIA, can simulate networks without mobile queues, but only low power integrated devices, for example wireless sensor networks (WSN). For this, INET is the platform used in vehicle network simulation scenarios [124].

ICanCloud

ICanCloud is a simulation tool for modeling and simulating cloud computing systems, designed for people who work with these systems often. The fundamental goal of this platform is to forecast the cost-performance trade-offs of a collection of applications operating on certain hardware, and then to offer users with meaningful cost information. However, it can be used by a large number of users, from basic active users to developers of large distributed applications [125].

Among these advantages, one of the principles of these design is the possibility of conducting large experiments. This is why iCanCloud supports the C ++ language. Thanks to this, iCanCloud can use all the memory available on the machines running the experiments, for 32 and 64 bit machines, because other CloudSim simulators for example, can not handle more than 2 GB of memory in 32 bit systems due to the fact that it is written in Java. An extension of the NS2 Network Simulator, GreenCloud focuses on simulating communications between processes running in a cloud at the packet level. Similar to NS2, GreenCloud is written in C ++ and OTcl, which is a drawback. You have to use two different languages to implement a single experiment. On the other hand, ICanCloud is written only in C ++ [125].

One of the issues with cloud computing is data center power usage; even iCanCloud does not give power consumption models, however this will be addressed in future development [125].

None of the existing cloud simulation tools (CloudSim, MDCSim and GreenCloud) have a full graphical interface. On the other hand, iCanCloud has a simple graphical interface that allows users to easily create experiments [125].

The main disadvantage of the existing platforms (CloudSim, MDCSim and GreenCloud) is a design principle in ICanCloud. The existing simulation tools can only simulate one experiment on one machine at a time. However, ICanCloud can simulate an experiment on a group of machines [125].

Integrating ICanCloud with INET

In iCanCloud, the network system allows applications running in virtual machines to exchange data through a communications network. In order to fulfill this task, the INET platform was used. This platform contains modules allowing you to completely simulate a network system. It contains network protocols such as TCP and UDP. The main advantage of this method is the high level of precision obtained, because all the elements making up a network are simulated. The main drawback, on the other hand, is performance, as this high level of detail requires a considerable calculation of processor power. Also, the INET framework provides a set of modules, such as routers, switches and network protocols, to create a wide range of networks [125].

2 The study scenario

In our study scenario, the vehicular Fog Computing servers host an application based on the Client/Server model, allowing services to be provided to the OBU (s) of cars via the use of cellular networks, namely LTE. The application is based on a single mode of communication, that is, vehicle-to-infrastructure communication (V2I). In addition, the connection between Fog servers and LTEs is wire-based, while the connection between LTE networks and vehicles is based on the DSRC (or IEEE 802.11p) standard.

2.1 Communication architecture

The communication architecture our scenario is an important step for the realization of our project. The objective of the architecture is to define the wireless access system to our vehicle network, as in the architecture predefined by the WAVE standard [25] The communication architecture that we propose follows the layered architecture of the model WAVE and the OSI (Open System Interconnection) model. However, this architecture integrates several protocols, namely Internet protocol (IPv4), ARP, ICMP, etc.

2.2 Vehicular fog project for video streaming

Tool versions used in this work : Omnet ++ v4.6 , INET v2.5 , ICanCloud v1.0.
Start the Omnet ++ IDE by typing omnet ++ in your terminal, as shown in figure 4.1 :

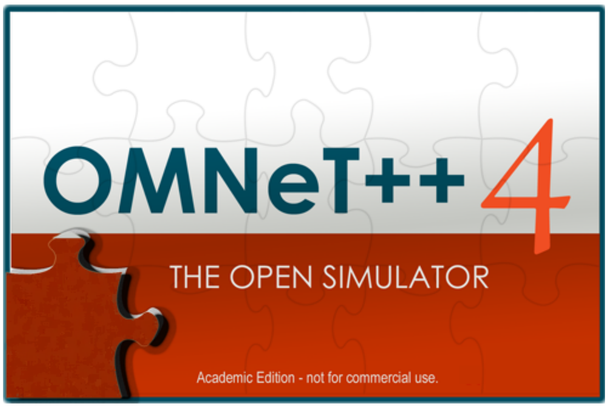


Figure 4.1 – Omnet++ IDE.

Once in the IDE, install The INET Framework and ICanCloud simulator.

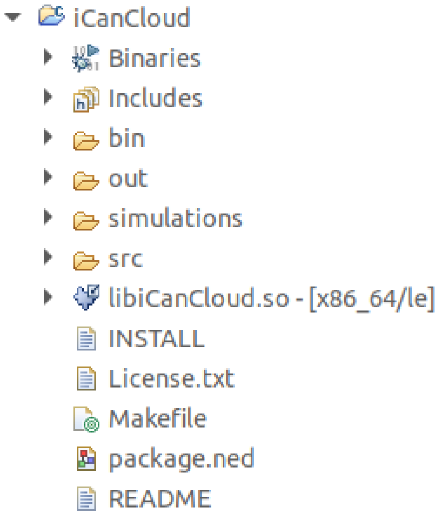
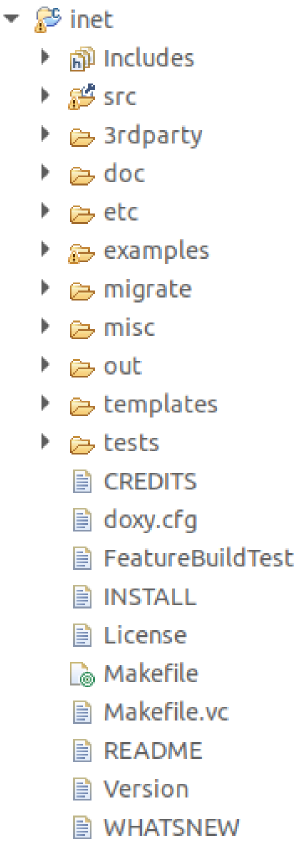

- iCanCloud
  - Binaries
  - Includes
  - bin
  - out
  - simulations
  - src
  - libiCanCloud.so - [x86_64/le]
  - INSTALL
  - License.txt
  - Makefile
  - package.ned
  - README

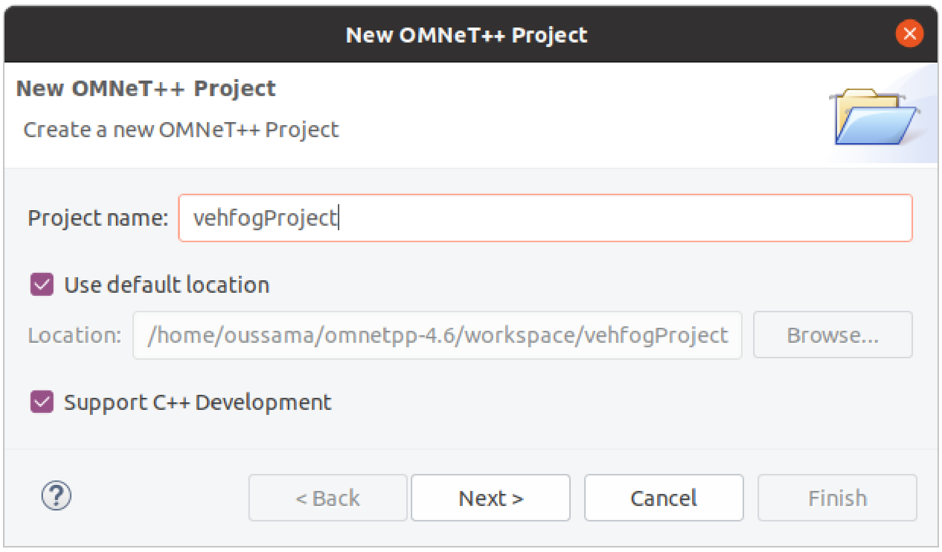
Figure 4.2 – IcanCloud folder.



- inet
  - Includes
  - src
  - 3rdparty
  - doc
  - etc
  - examples
  - migrate
  - misc
  - out
  - templates
  - tests
  - CREDITS
  - doxy.cfg
  - FeatureBuildTest
  - INSTALL
  - License
  - Makefile
  - Makefile.vc
  - README
  - Version
  - WHATSNEW

Figure 4.3 – INET folder.

The second phase is to create a new project, choose: New -> Omnet++ Project from the menu, as shown in figure 4.4 :



New OMNeT++ Project

New OMNeT++ Project

Create a new OMNeT++ Project

Project name: vehfogProject

☑ Use default location

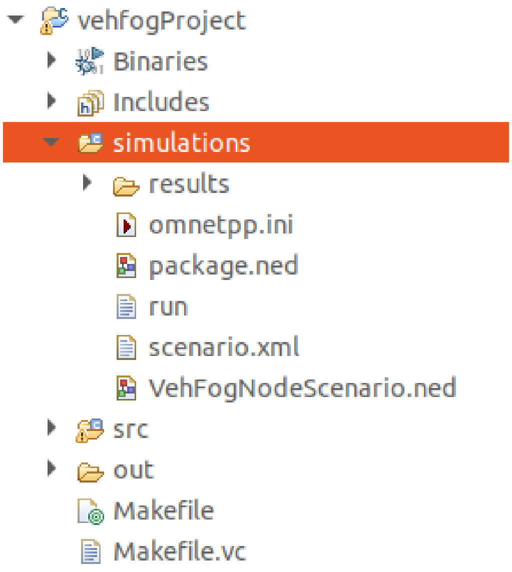
Location: /home/oussama/omnetpp-4.6/workspace/vehfogProject

☑ Support C++ Development

Figure 4.4 – Starting the project.

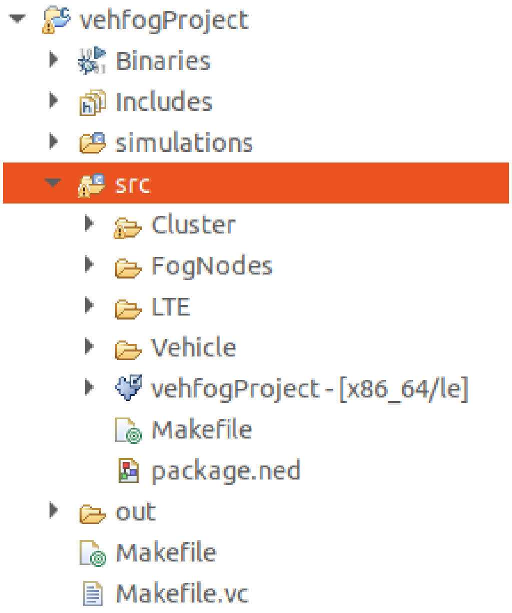
2.3 Vehicular fog environment for video streaming

Our project contains two essential containers that will be open, src and simulations. The folder simulation contains an omnetpp.ini configuration file, the latter taking the configuration of the topology (package.ned) see (figure 4.5). The configuration concerning must be the values after a predefined execution time,The src folder includes three files : Cluster and FogNode, LTE and see (figure 4.6). In the cluster folder we have defined the ClusterControl.ned calculation modules and its behavior. c++/.h, the Nodes folder takes all vehicle nodes from the base node to the VehicularFogNodeScenario.ned.



- vehfogProject
  - Binaries
  - Includes
  - simulations
    - results
    - omnetpp.ini
    - package.ned
    - run
    - scenario.xml
    - VehFogNodeScenario.ned
  - src
  - out
  - Makefile
  - Makefile.vc

Figure 4.5 – Folder of simulation.



- vehfogProject
  - Binaries
  - Includes
  - simulations
  - src
    - Cluster
    - FogNodes
    - LTE
    - Vehicle
    - vehfogProject - [x86_64/le]
    - Makefile
    - package.ned
  - out
  - Makefile
  - Makefile.vc

Figure 4.6 – Folder src.

The omnetpp.ini configuration file, as shown in figure 4.7 :

```
[General]
network = VehFogNodeScenario
#record-eventlog = true
#eventlog-message-detail-pattern = *:(not declaredOn(cMessage) and not declaredOn(cNamedObject) and not declaredOn(cObject))

tkenv-plugin-path = ../../../etc/plugins

*.numVeh = 30

# cluster control

**.clusterControl.fixedDistance = 200

# corrdinnate

**.constraintAreaMinX = 0m
**.constraintAreaMinY = 0m
**.constraintAreaMinZ = 0m
**.constraintAreaMaxX = 600m
**.constraintAreaMaxY = 400m
**.constraintAreaMaxZ = 0m

**.debug = true
**.coreDebug = false
**.channelNumber = 0

# channel physical parameters
*.channelControl.carrierFrequency = 2.4GHz
*.channelControl.pMax = 20.0mW
*.channelControl.sat = -110dBm
*.channelControl.alpha = 2
```

Figure 4.7 – omnetpp.ini file.

2.4 Build and run simulations

The following components make up an OMNeT ++ model :

Description of the NED topology(.ned files)

Describe the module's structure, including parameters, doors, and so forth. NED files may be created with any text editor, however the OMNeT ++ IDE has great graphical and bidirectional text editing features. Figure 4.8 shows an example of a .ned file.

Message definitions (.msg files)

Message kinds are defined here, as well as data fields. OMNeT ++ converts message definitions to complete C++ classes.

Simple module sources

These are C ++ files, with the suffix .h / .cc. an example of .ned file shown in figure 4.9.

Simulation kernel

This contains the code that manages the simulation and the library of simulation classes. It is written in C ++.

User interfaces

The simulation is conducted using OMNeT ++ user interfaces to make troubleshooting, demonstration, and execution of many simulations easier. They are written in the C++ programming language.

Omnetpp.ini

An omnetpp.ini file must be produced before the simulation can be started. omnetpp.ini includes parameters that govern the simulation's execution as well as model parameter values.

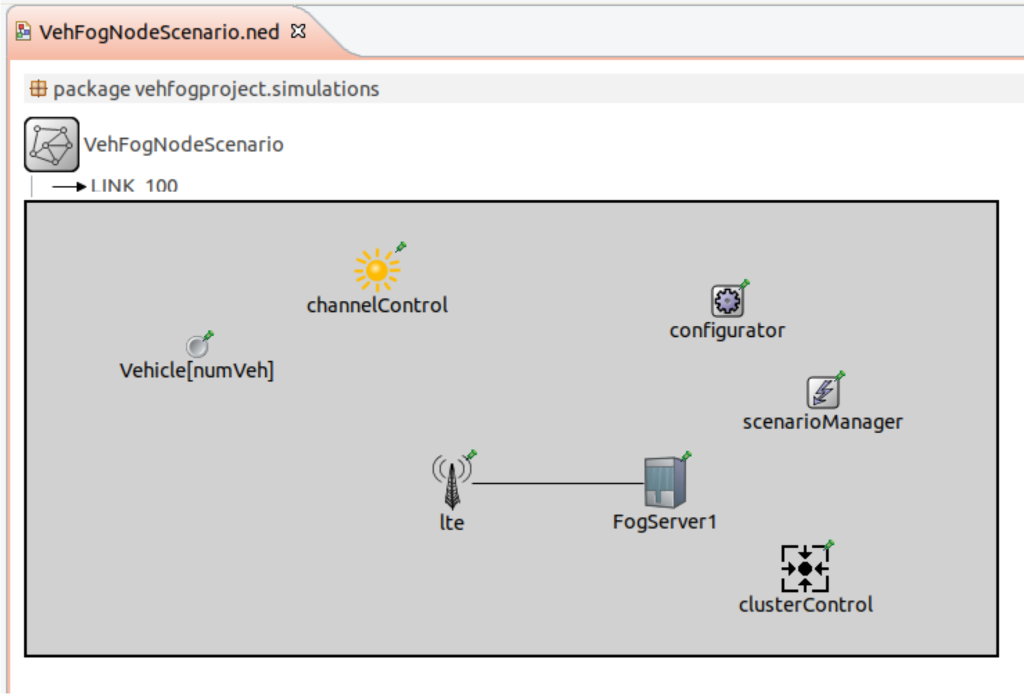
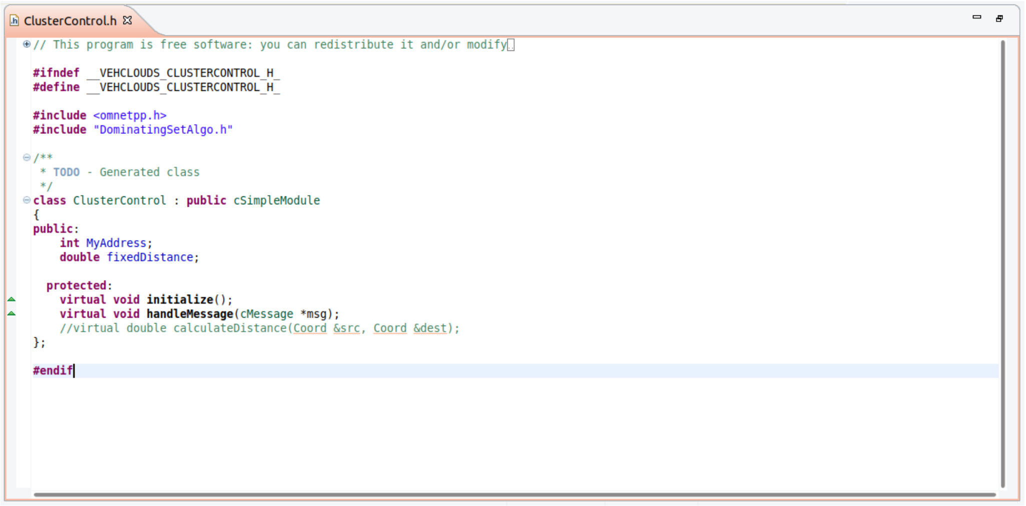


Figure 4.8 – .ned file.

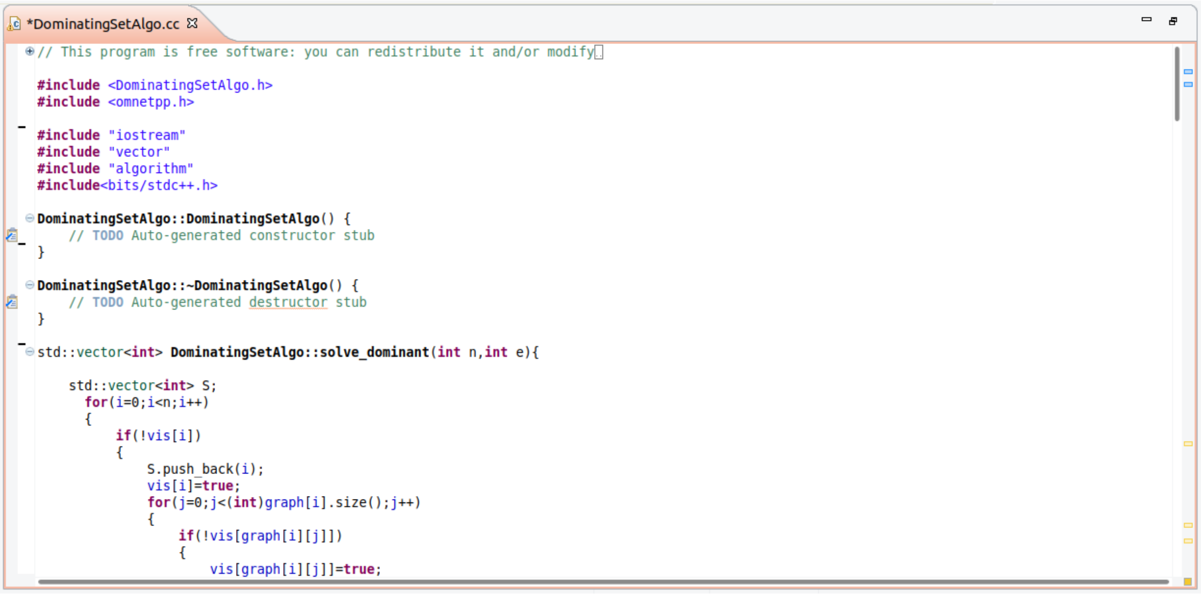


```
// This program is free software: you can redistribute it and/or modify

#ifndef __VEHCLOUDS_CLUSTERCONTROL_H_
#define __VEHCLOUDS_CLUSTERCONTROL_H_

#include <omnetpp.h>
#include "DominatingSetAlgo.h"

/**
 * TODO - Generated class
 */
class ClusterControl : public cSimpleModule
{
public:
    int MyAddress;
    double fixedDistance;

  protected:
    virtual void initialize();
    virtual void handleMessage(cMessage *msg);
    //virtual double calculateDistance(Coord &src, Coord &dest);
};

#endif
```

Figure 4.9 – File ClusterControl.h.

3 The implementation

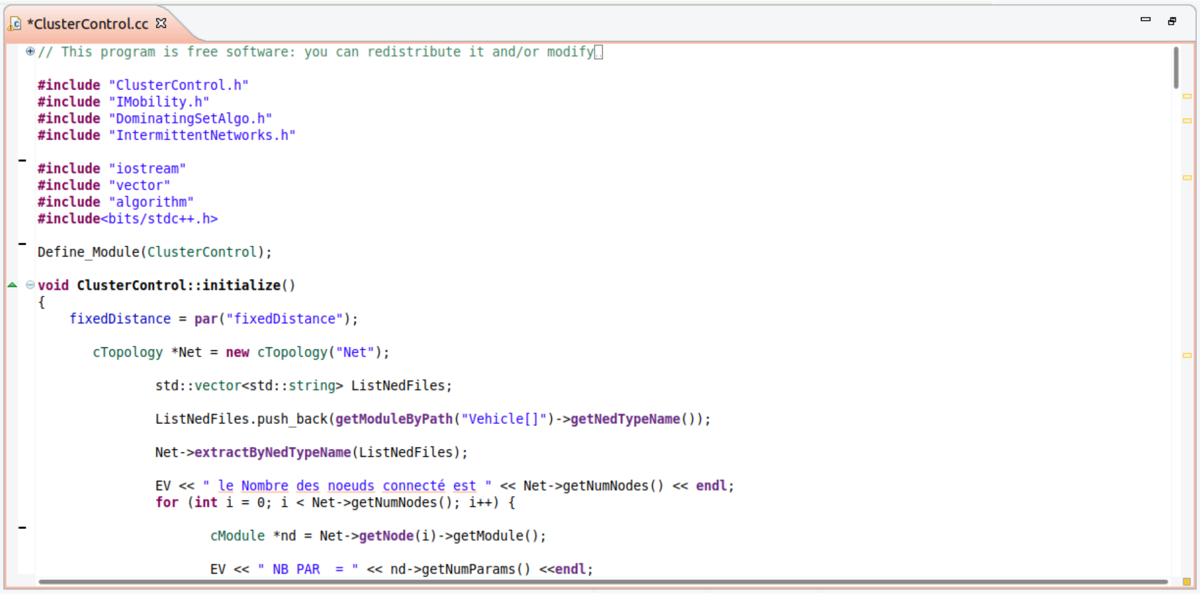
3.1 Dominant Sets Algorithm



```
// This program is free software: you can redistribute it and/or modify

#include <DominatingSetAlgo.h>
#include <omnetpp.h>

#include "iostream"
#include "vector"
#include "algorithm"
#include<bits/stdc++.h>

DominatingSetAlgo::DominatingSetAlgo() {
    // TODO Auto-generated constructor stub
}

DominatingSetAlgo::~DominatingSetAlgo() {
    // TODO Auto-generated destructor stub
}

std::vector<int> DominatingSetAlgo::solve_dominant(int n,int e){

    std::vector<int> S;
      for(i=0;i<n;i++)
      {
          if(!vis[i])
          {
              S.push_back(i);
              vis[i]=true;
              for(j=0;j<(int)graph[i].size();j++)
              {
                  if(!vis[graph[i][j]])
                  {
                      vis[graph[i][j]]=true;
```

Figure 4.10 – Dominant set.

3.2 Cluster Control

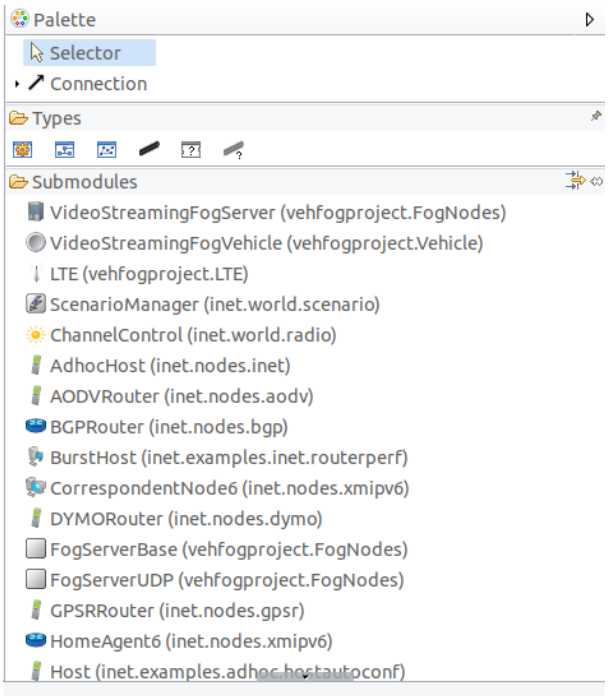


```
// This program is free software: you can redistribute it and/or modify

#include "ClusterControl.h"
#include "IMobility.h"
#include "DominatingSetAlgo.h"
#include "IntermittentNetworks.h"

#include "iostream"
#include "vector"
#include "algorithm"
#include<bits/stdc++.h>

Define_Module(ClusterControl);

void ClusterControl::initialize()
{
    fixedDistance = par("fixedDistance");

       cTopology *Net = new cTopology("Net");

               std::vector<std::string> ListNedFiles;

               ListNedFiles.push_back(getModuleByPath("Vehicle[]")->getNedTypeName());

               Net->extractByNedTypeName(ListNedFiles);

               EV << " le Nombre des noeuds connecté est " << Net->getNumNodes() << endl;
               for (int i = 0; i < Net->getNumNodes(); i++) {

                      cModule *nd = Net->getNode(i)->getModule();

                      EV << " NB PAR  = " << nd->getNumParams() <<endl;
```

Figure 4.11 – Cluster control.

4 Nodes of simulation

You may create a simulation by utilizing the OMNET palette, which contains the different modules of the ICanCloud platform and INET, as well as the other referred platforms (MiXiM, Castalia, and so on), as shown in figure 4.12.



Palette
Selector
Connection
Types
Submodules
VideoStreamingFogServer (vehfogproject.FogNodes)
VideoStreamingFogVehicle (vehfogproject.Vehicle)
LTE (vehfogproject.LTE)
ScenarioManager (inet.world.scenario)
ChannelControl (inet.world.radio)
AdhocHost (inet.nodes.inet)
AODVRouter (inet.nodes.aodv)
BGPRouter (inet.nodes.bgp)
BurstHost (inet.examples.inet.routerperf)
CorrespondentNode6 (inet.nodes.xmipv6)
DYMORouter (inet.nodes.dymo)
FogServerBase (vehfogproject.FogNodes)
FogServerUDP (vehfogproject.FogNodes)
GPSRRouter (inet.nodes.gpsr)
HomeAgent6 (inet.nodes.xmipv6)
Host (inet.examples.adhoc.hostautoconf)

Figure 4.12 – Palette of omnet++.

As illustrated in figure 4.13, the topology (VehFogNodeScenario) is made up of numerous simple and compound modules, including vehicular nodes, ClusterControl, and other INET platform nodes, channelControl, confi-gurator, and scenarioManager.

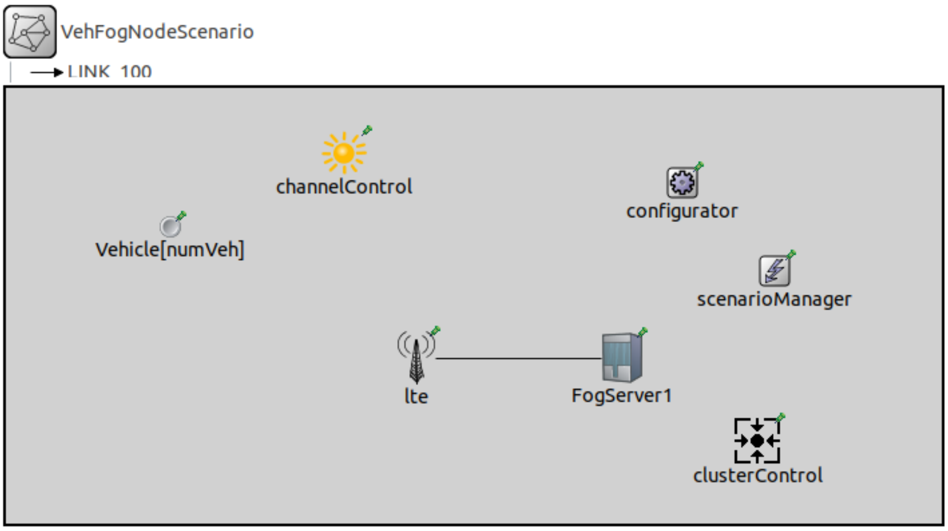
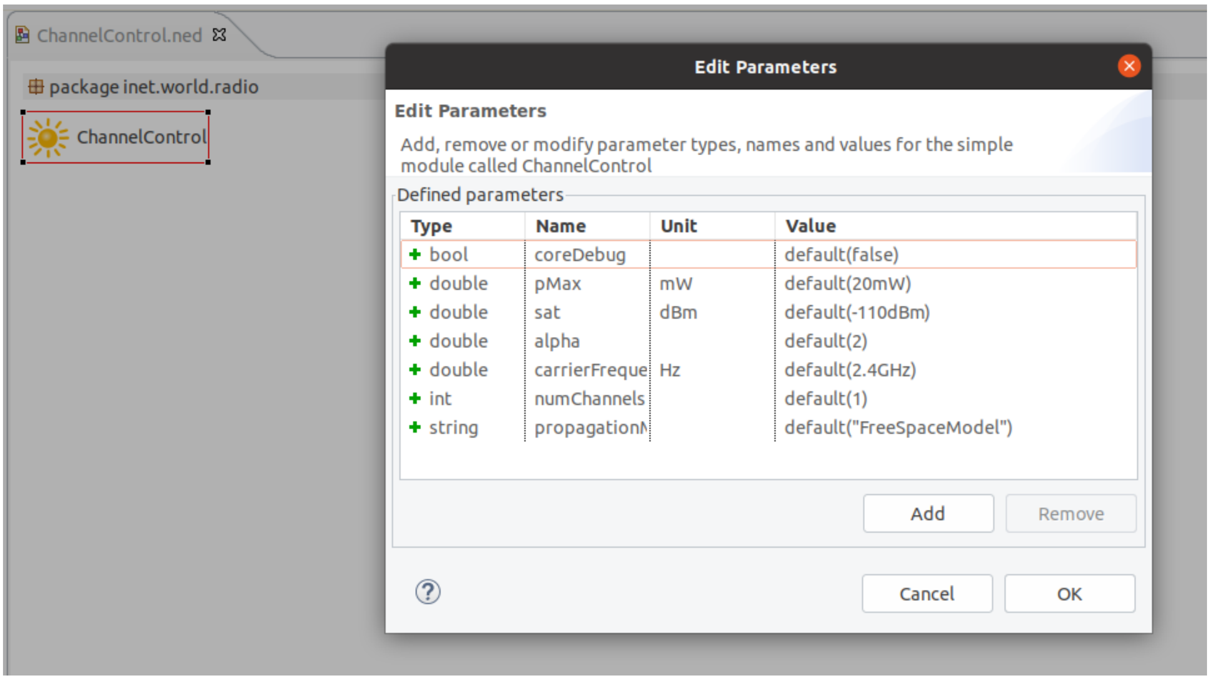


Figure 4.13 – The topology of our project.

4.1 Channel management

Every network model with mobile or wireless nodes has precisely one instance of ChannelControl. This module receives information about node position and mobility and decides which nodes are within communication or interference range. The radio interfaces of nodes then utilise this information during broadcasts. Must be named as "channelControl" inside the network, as shown in figure 4.14.



Add, remove or modify parameter types, names and values for the simple module called ChannelControl

Defined parameters

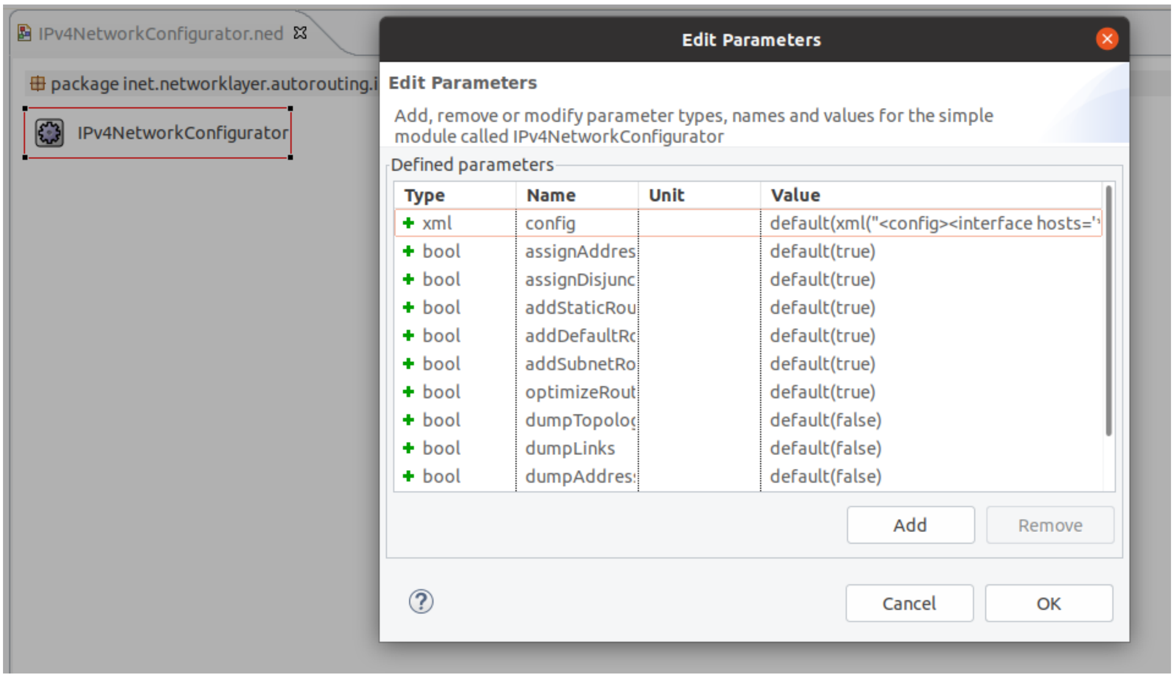
Type	Name	Unit	Value
bool	coreDebug		default(false)
double	pMax	mW	default(20mW)
double	sat	dBm	default(-110dBm)
double	alpha		default(2)
double	carrierFreque	Hz	default(2.4GHz)
int	numChannels		default(1)
string	propagationN		default("FreeSpaceModel")

Figure 4.14 – Channel Control.

4.2 IPv4 Network Configurator

In an IPv4 network, his module allocates IP addresses and configures static routing. It allocates IP addresses per interface, attempts to account for subnets, and may also merge routing entries to improve the resulting routing tables.

When compared to the number of nodes, hierarchical routing may be set up with a small amount of configuration entries. As seen in Figure 4.15, In large networks, the configurator also does routing table optimization, which significantly decreases the size of routing tables.



Edit Parameters

Add, remove or modify parameter types, names and values for the simple module called IPv4NetworkConfigurator

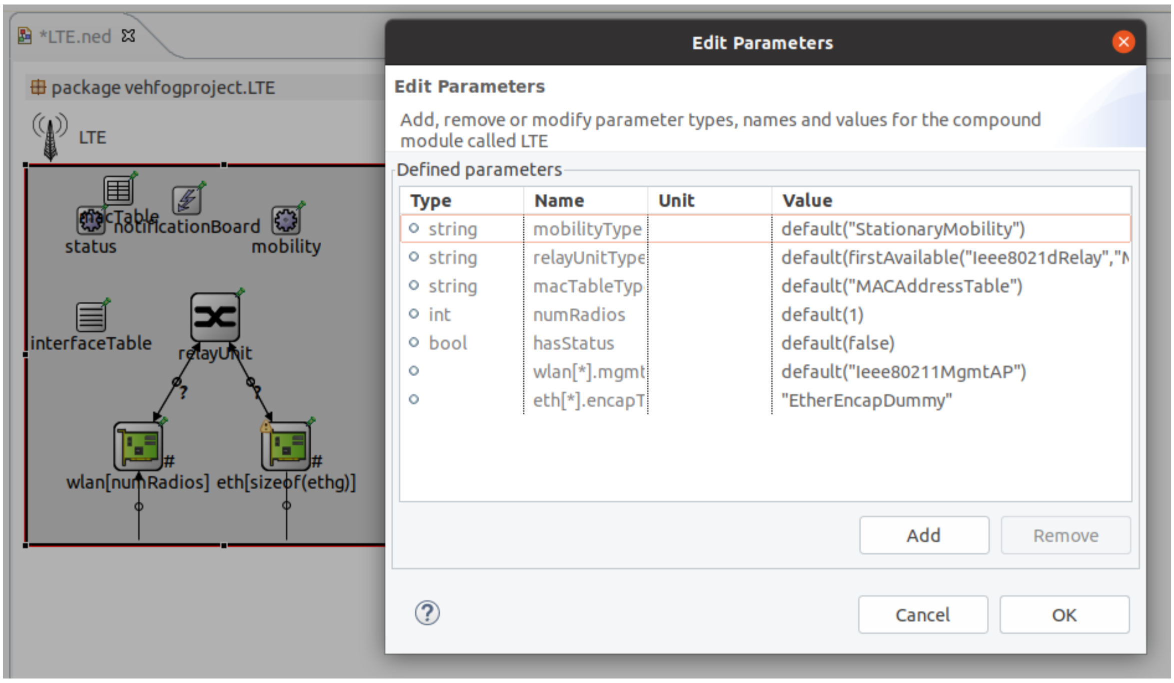
Defined parameters

Type	Name	Unit	Value
+ xml	config		default(xml("<config><interface hosts='
+ bool	assignAddres		default(true)
+ bool	assignDisjunc		default(true)
+ bool	addStaticRou		default(true)
+ bool	addDefaultRc		default(true)
+ bool	addSubnetRo		default(true)
+ bool	optimizeRout		default(true)
+ bool	dumpTopolog		default(false)
+ bool	dumpLinks		default(false)
+ bool	dumpAddres		default(false)

Figure 4.15 – IPv4 Network Configurator.

4.3 LTE Acess point

As illustrated in figure 4.16, the Long Term Evolution (LTE) network infrastructure is responsible for connection requests, which effectively means it's the one left asking for permission when it's time to connect to another network.



Edit Parameters

Add, remove or modify parameter types, names and values for the compound module called LTE

Defined parameters

Type	Name	Unit	Value
○ string	mobilityType		default("StationaryMobility")
○ string	relayUnitType		default(firstAvailable("Ieee8021dRelay","N
○ string	macTableTyp		default("MACAddressTable")
○ int	numRadios		default(1)
○ bool	hasStatus		default(false)
○	wlan[*].mgmt		default("Ieee80211MgmtAP")
○	eth[*].encapT		"EtherEncapDummy"

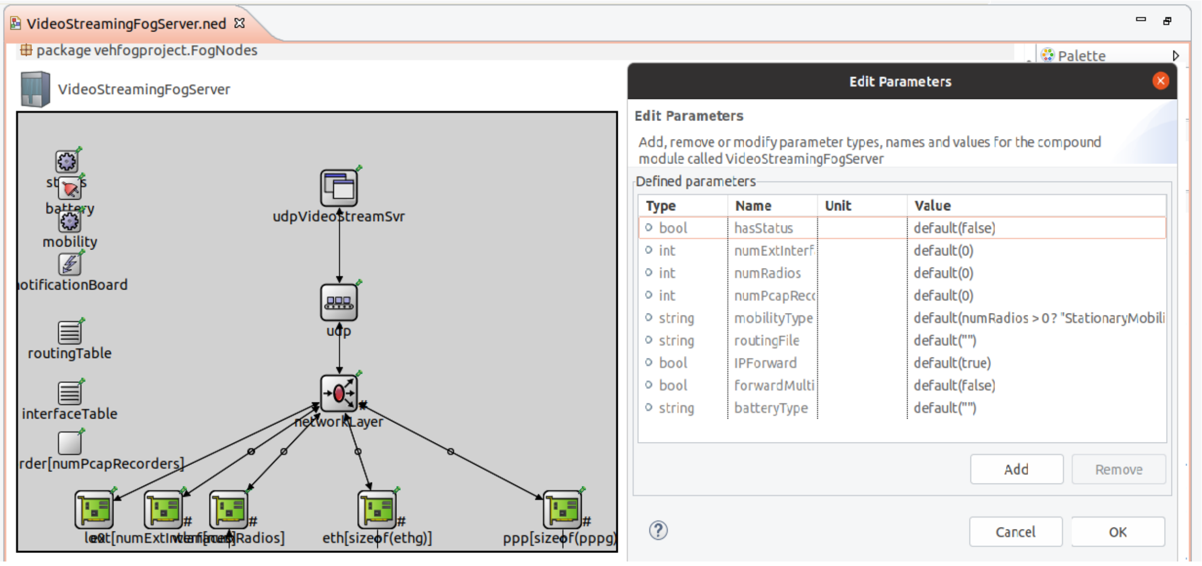
Figure 4.16 – LTE Acess point.

4.4 fog server

Contains the application of Video stream server. To be used with UDPVideoStreamClient. The server will wait for incoming "video streaming requests". When a request arrives, it draws a random video stream size using the videoSize parameter, and starts streaming to the client. During streaming, it will send UDP packets of size packetLenght at every sendInterval, until videoSize is reached The server can serve several clients, and several streams per client. Statistics :

reqStreamBytes statistic of bytelength of requested video streams.

sentPkBytes statistic of sent packets and sent bytes.



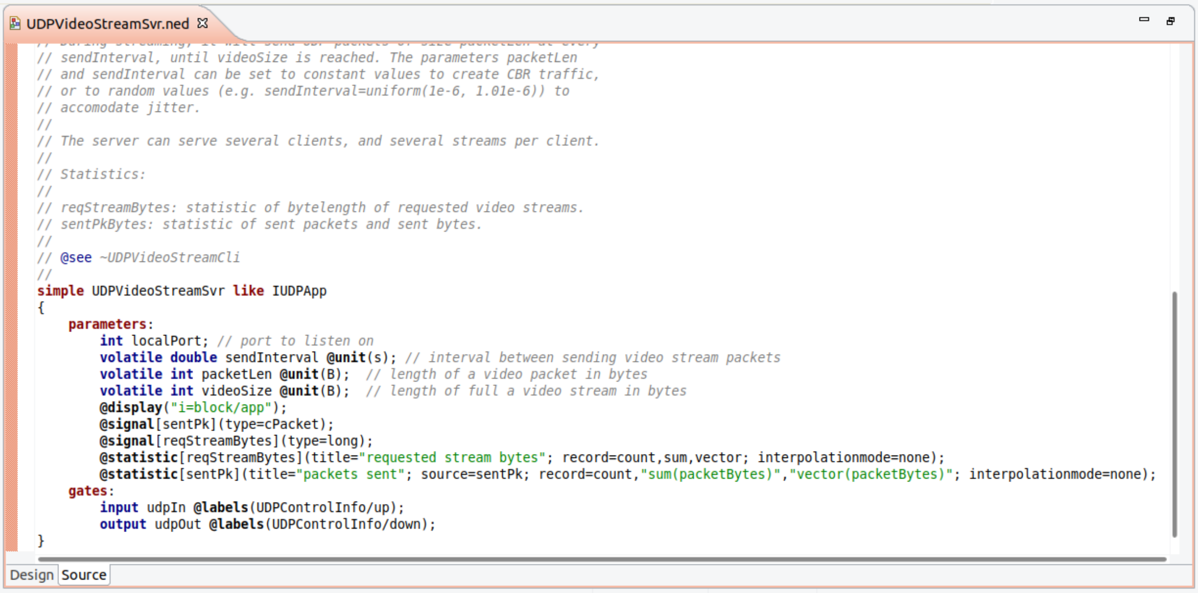
Edit Parameters

Add, remove or modify parameter types, names and values for the compound module called VideoStreamingFogServer

Defined parameters

Type	Name	Unit	Value
bool	hasStatus		default(false)
int	numExtInterf		default(0)
int	numRadios		default(0)
int	numPcapRecc		default(0)
string	mobilityType		default(numRadios > 0 ? "StationaryMobili
string	routingFile		default("")
bool	IPForward		default(true)
bool	forwardMulti		default(false)
string	batteryType		default("")

Figure 4.17 – Fog Server.

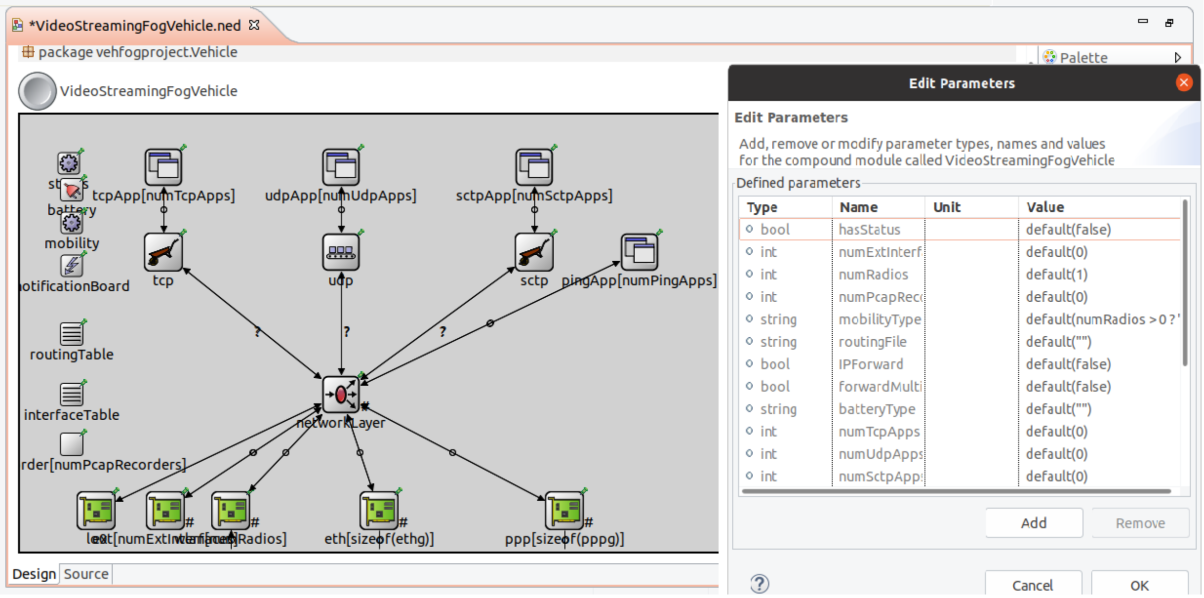


```
// sendInterval, until videoSize is reached. The parameters packetLen
// and sendInterval can be set to constant values to create CBR traffic,
// or to random values (e.g. sendInterval=uniform(1e-6, 1.01e-6)) to
// accomodate jitter.
//
// The server can serve several clients, and several streams per client.
//
// Statistics:
//
// reqStreamBytes: statistic of bytelength of requested video streams.
// sentPkBytes: statistic of sent packets and sent bytes.
//
// @see ~UDPVideoStreamCli
//
simple UDPVideoStreamSvr like IUDPApp
{
    parameters:
        int localPort; // port to listen on
        volatile double sendInterval @unit(s); // interval between sending video stream packets
        volatile int packetLen @unit(B);  // length of a video packet in bytes
        volatile int videoSize @unit(B);  // length of full a video stream in bytes
        @display("i=block/app");
        @signal[sentPk](type=cPacket);
        @signal[reqStreamBytes](type=long);
        @statistic[reqStreamBytes](title="requested stream bytes"; record=count,sum,vector; interpolationmode=none);
        @statistic[sentPk](title="packets sent"; source=sentPk; record=count,"sum(packetBytes)","vector(packetBytes)"; interpolationmode=none);
    gates:
        input udpIn @labels(UDPControlInfo/up);
        output udpOut @labels(UDPControlInfo/down);
}
```

Figure 4.18 – UDP video streaming packet(Server).

4.5 Vehicular fog node

The vehicle is a module made up of a set of simple or composed modules that are part of the Cloud Computing extracted from iCanCloud: osModule, StorageSystem, memory, and UDP application, TCP application, cpuModule, and other INET modules: tcp, networkLayer, DSRC, mobility, routingTable, interface-Table, and energyMeter, as shown in figure 4.19.



Edit Parameters

Add, remove or modify parameter types, names and values for the compound module called VideoStreamingFogVehicle

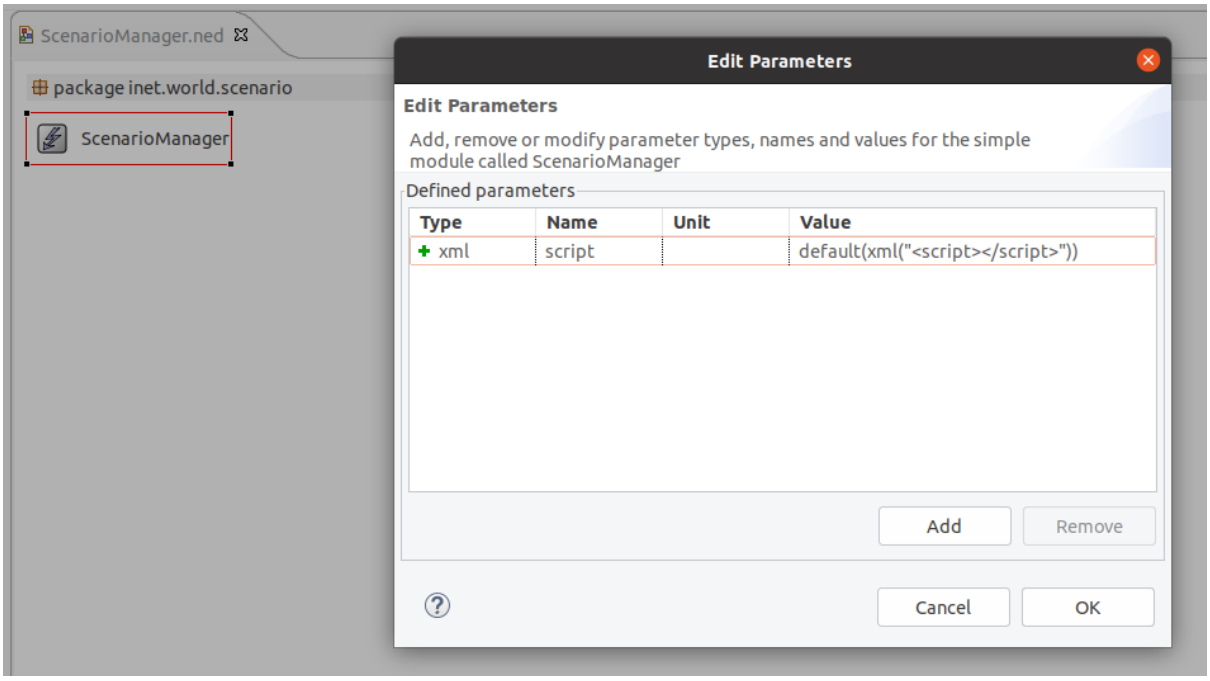
Defined parameters

Type	Name	Unit	Value
○ bool	hasStatus		default(false)
○ int	numExtInterf		default(0)
○ int	numRadios		default(1)
○ int	numPcapRec		default(0)
○ string	mobilityType		default(numRadios > 0 ? '
○ string	routingFile		default("")
○ bool	IPForward		default(false)
○ bool	forwardMulti		default(false)
○ string	batteryType		default("")
○ int	numTcpApps		default(0)
○ int	numUdpApps		default(0)
○ int	numSctpApp		default(0)

Figure 4.19 – Vehicular fog node.

4.6 Scenario manager

ScenarioManager is a program that allows you to set up and manage simulation studies. You may schedule specific actions, such as altering a parameter value, changing a connection's bit error rate, deleting or adding connections, removing or adding routes in a routing table, and so on, to monitor the temporary behavior, as illustrated in figure 4.20.



Edit Parameters

Add, remove or modify parameter types, names and values for the simple module called ScenarioManager

Defined parameters

Type	Name	Unit	Value
xml	script		default(xml("<script></script>"))

Figure 4.20 – Scenario manager.

5 Simulation

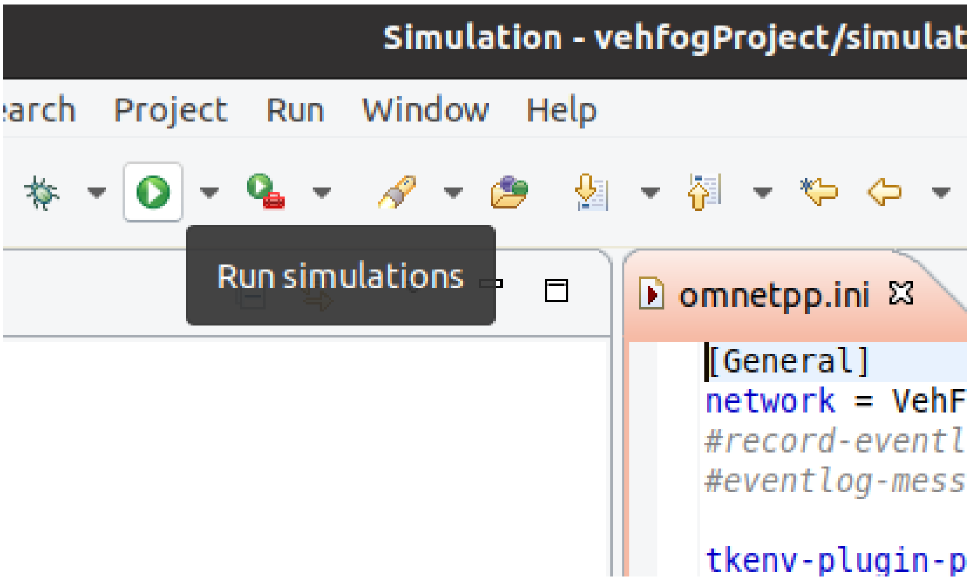
5.1 Simulation parameters

Table 4.1 – Parameters of simulation.

Parameters	Value
Frequency Band	2.4GHz
Mobility Type	MassMobility
Update Interval	100ms
Transmission range	600 m
Max number of vehicles/h	30
Mobility speed	truncnormal(20mps, 8mps)

5.2 Start the simulation

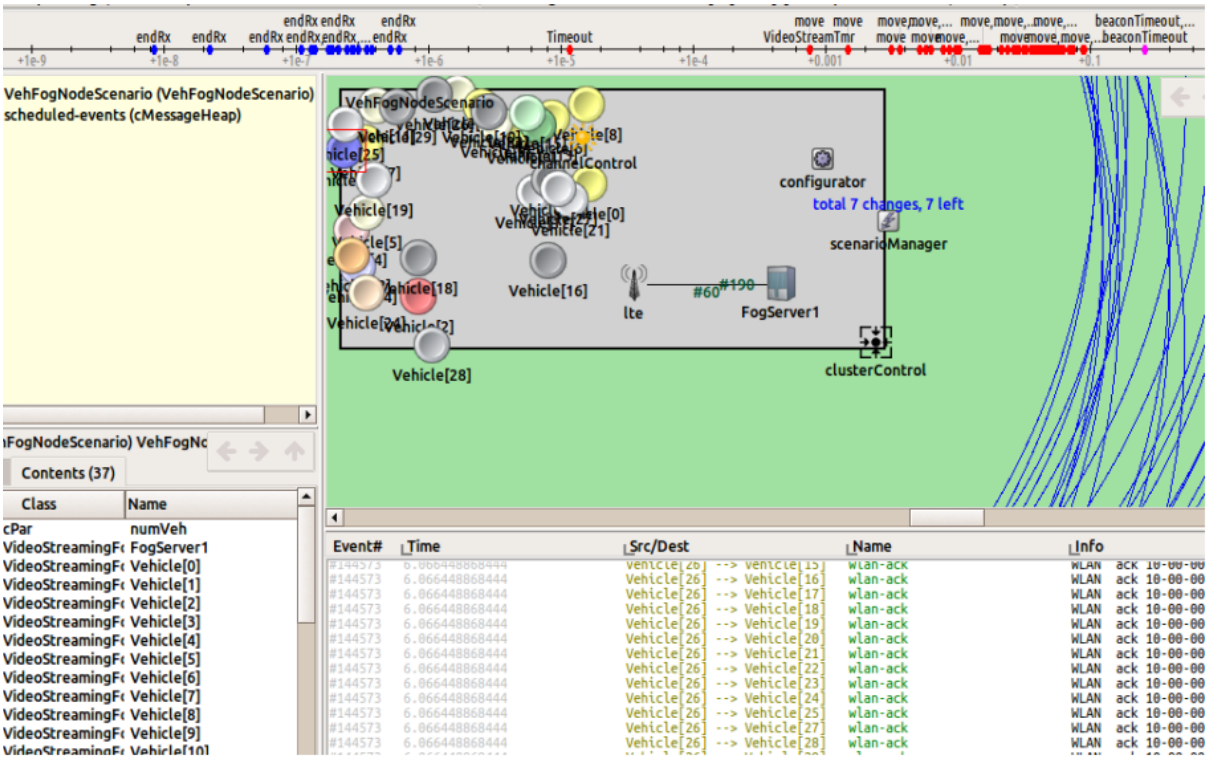
After you've performed the preceding steps, open the project explorer and choose omnetpp.ini, then hit the Run button, as seen in Figure 4.21.



```
[General]
network = VehF
#record-eventl
#eventlog-mess

tkenv-plugin-p
```

Figure 4.21 – Start the simulation.

The IDE is an acronym for Integrated Development Environment. Automatically create your project. If there are any compilation issues, you must correct them until the compilation and link are error-free. Select Project -> Build All from the menu or press Ctrl + B to manually start the build. You should see a new graphics window, similar to the one in the picture below, after successfully constructing and running your simulation. The network comprising the nodes should also be graphically represented in the main section. To begin the simulation, press the Run button on the toolbar. What you should notice is that automobiles are communicating with one another. The car nodes will be initialized following the Simulation Run, and one of the nodes will transmit a message through a radio interface.



Class	Name
cPar	numVeh
VideoStreamingF	FogServer1
VideoStreamingF	Vehicle[0]
VideoStreamingF	Vehicle[1]
VideoStreamingF	Vehicle[2]
VideoStreamingF	Vehicle[3]
VideoStreamingF	Vehicle[4]
VideoStreamingF	Vehicle[5]
VideoStreamingF	Vehicle[6]
VideoStreamingF	Vehicle[7]
VideoStreamingF	Vehicle[8]
VideoStreamingF	Vehicle[9]
VideoStreamingF	Vehicle[10]

```
Event#   Time               Src/Dest                      Name        Info
#144573  6.066448868444     Vehicle[26] --> Vehicle[15]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[16]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[17]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[18]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[19]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[20]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[21]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[22]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[23]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[24]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[25]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[27]   wlan-ack    WLAN  ack 10-00-00
#144573  6.066448868444     Vehicle[26] --> Vehicle[28]   wlan-ack    WLAN  ack 10-00-00
```

Figure 4.22 – run the simulation of video streaming.

The first message sent activates the Cluster Controller module, this module is responsible of several tasks, first, it extracts all the nodes in the topology and the different links between these nodes, afterwards, it creates the possible referent clusters and the dominant groups of each cluster where each cluster will be colored with one color and its dominant group with another color their, Figure represents the different clusters and their dominant groups.

During simulations, each component does an action, to see the behavior of this module, just double click on it. After launching the simulation, the Cluster module Controller extracts the sub-network referees, the number of sub-networks and the groups (Dominant Set) as illustrated in the (figure 4.22).

6 performance analysis

6.1 Turning on ACKs

As part of a communications protocol, acknowledgment (ACK) is a radio signal that is transmitted between topological nodes or devices to mark receipt of a message.

Goals

By introducing acknowledgments to the MAC protocol in this phase, we hope to improve the reliability of link layer communication.

The model

By changing the useAcks parameter of CsmaCaMac to true, we enable acknowledgments. The operation of the MAC module will be both more fascinating and more difficult as a result of this adjustment.

The modification on the receiver side is straightforward: after properly receiving a data frame designated to it, the MAC responds with an ACK frame after a fixed-length interval (SIFS). If the data frame's originator does not get the ACK in a timely manner, it will begin a re-transmission. For each re-transmission, the contention window (from which the random back-off period is selected) will be increased until it reaches the maximum (and then it will stay constant for further re-transmissions). The MAC will give up after a certain number of failed retries, discard the data frame, and accept the next data frame from the queue. The following frame will begin with a blank canvas (i.e. the contention window and the retry count will be reset).

This procedure is similar to the fundamental IEEE 802.11b MAC ad-hoc mode procedure.

Re-transmissions will introduce duplicates in the packet stream that the MAC delivers up to the higher layer protocols in the recipient host when ACKs (in contrast to data frames) are lost. This might be avoided by adding sequence numbers to frames and keeping per-sender sequence numbers in each receiver, however the CsmaCaMac module lacks such a duplication detection method to make its code simple and accessible.

The MAC generates a link break signal when a frame exceeds the maximum number of retries and is discarded. Routing protocols like AODV may interpret this signal as an indication that a route has broken and a new one has to be sought.

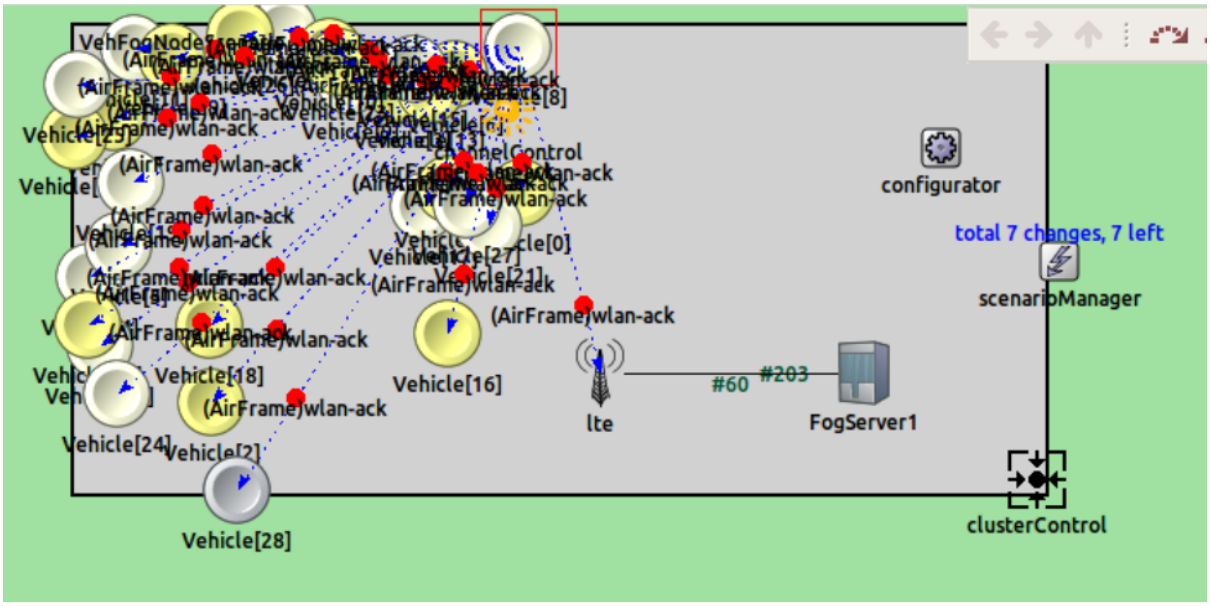


Figure 4.23 – Wlan-ack messages.

Video streaming packets

Vehicles send a VideoStrmReq packet to request the video stream at the start. As a result, Fog Server begins sending video stream packet fragments to cars. Because the packets' size exceeds the Maximum Transmission Unit, they are fragmented. The first packet fragment, VideoStrmPk-frag0 causes data link activity only at protocol level and at peer level, because other packet fragments are required to allow the packet to be forwarded to higher layers. When cars get VideoStrmPk-frag1, the packet is reconstructed and delivered to the top levels. As a consequence, a green arrow between videoServer and person1 is displayed, indicating data connection activity at the service level.

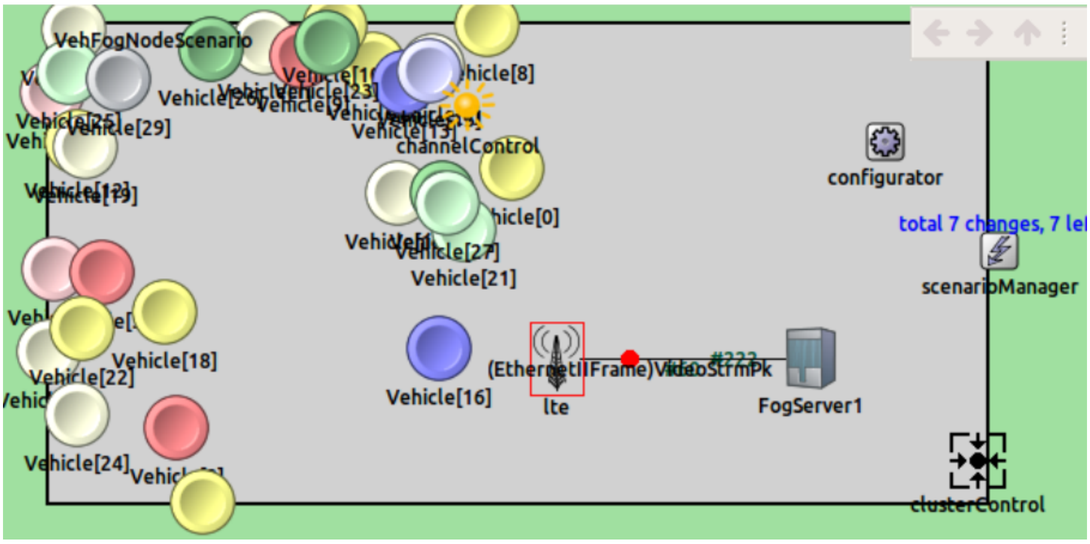


Figure 4.24 – Video streaming packets.

The following figure describes LTE forwarding video packets received from the fog server to all vehicles in the network.

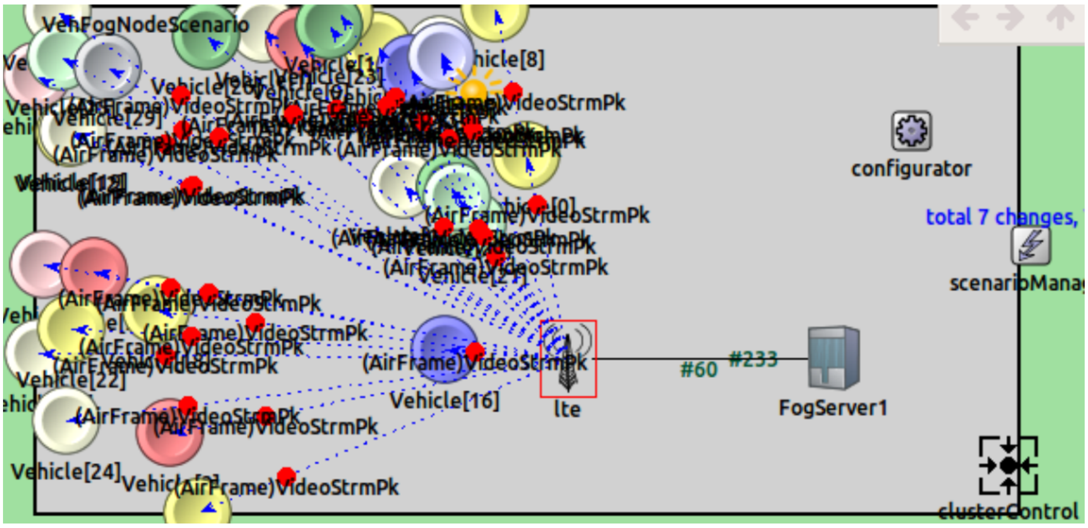


Figure 4.25 – Video streaming packets to all.

6.2 graph results

Radio state

The radio model denotes a physical instrument capable of sending and receiving signals via a medium. Models for an antenna, a transmitter, a receiver, and an energy consumer are all included.

The figure below depicts the kinds′ use connections.

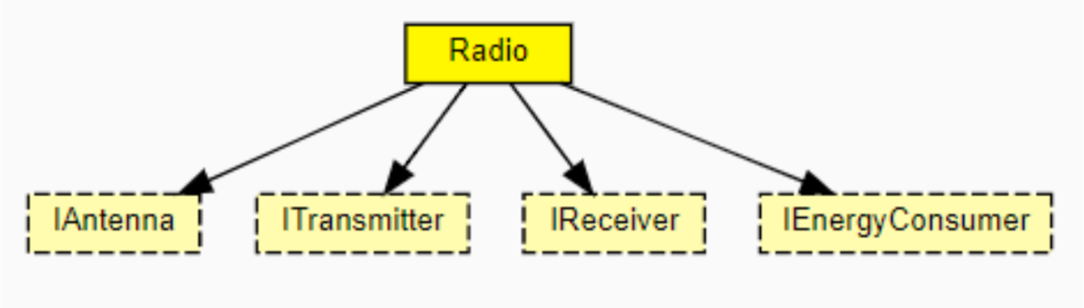


Figure 4.26 – Usage diagram.

Changes in radio mode, transmission power, and bitrate are all supported by the radio model. In our simulation, the radio status changes as shown in the next figure.

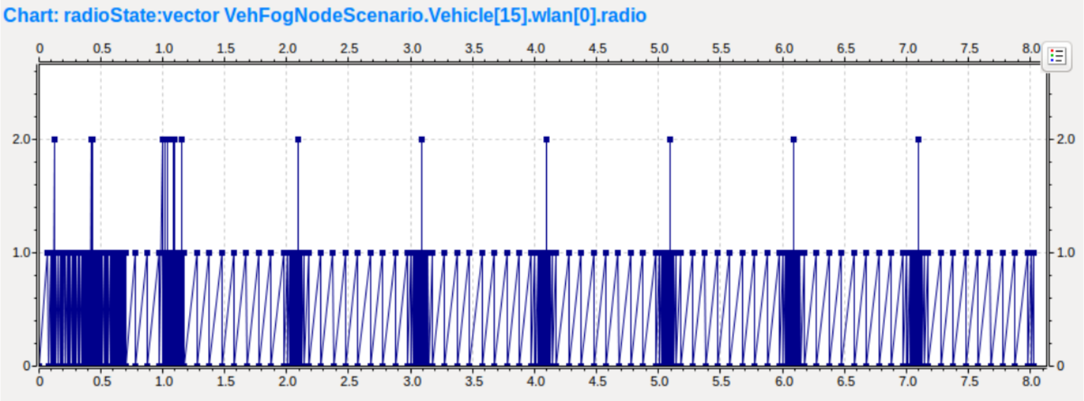


Figure 4.27 – Radio state graph.

the previous graph shows that radio state in the beginning of simulation is heavy due to the process of beaconing exchanged between all network nodes but the rest of simulation we see that radio state is balanced.

Packet Sent To Lower

AckingMac This module defines a simple MAC protocol that may be used with the AckingWireless Interface.

The implementation can encapsulate and decapsulate packets, but it lacks a true medium access protocol. It lacks a carrier sensing mechanism, collision avoidance, and collision detection, although it does offer out-of-band acknowledgement as an alternative. The MacAddressReq tag should be included in higher layer packets.

The following diagram shows usage relationships between types.

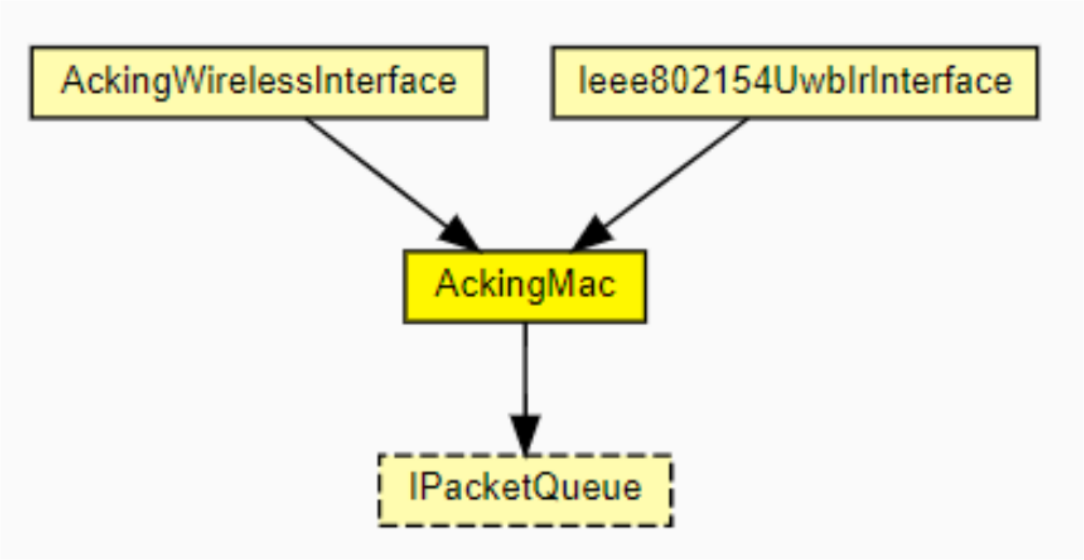


Figure 4.28 – Usage diagram.

next figure shows Packets Sent To Lower layer changes in our simulation.

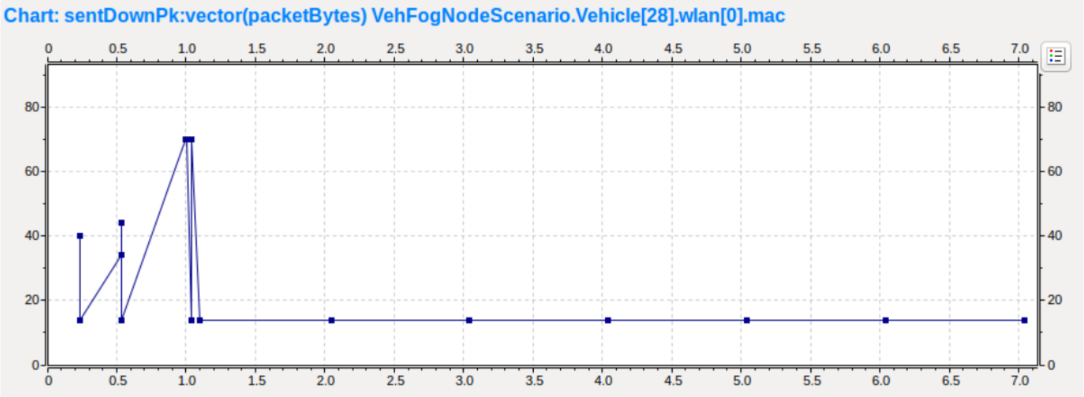


Figure 4.29 – Sent down packets.

the previous graph shows that sent down packets also in the start of simulation is heavy due to the process of beaconing exchanged between all network nodes but the rest of simulation we see that sent down packets is also balanced and there is no latency despite the mobility of nodes.

End to end delay

In this part, we'll look at how packet routing impacts packet end-to-end latency. Because packets might wait in the queue for a long period before being delivered, the length of packet queues in the MAC can have a considerable impact on latency. If the traffic exceeds the maximum allowable throughput, lines will form and the delay will grow. Queues will not fill up if traffic is less than the maximum feasible throughput (no additional delay), but performance will be less than the maximum attainable. The performance is best and the delay is reduced when traffic is equal to the maximum achievable throughput (we configured traffic this way).

Because packets do not have to wait as long in the queue to be part of an aggregate frame, the next graph has the shortest latency. The latency is longer when using best effort priority aggregation. Because the packets that make up the aggregate frame are transmitted to the UDP app at the same time, the numerous data points above each other signal the reception of an aggregate frame. Because the earliest packet in the aggregate frame has spent the most time in the transmission queue, it has the greatest delay. because while transmitting packets, the MAC waits shorter before obtaining the channel.

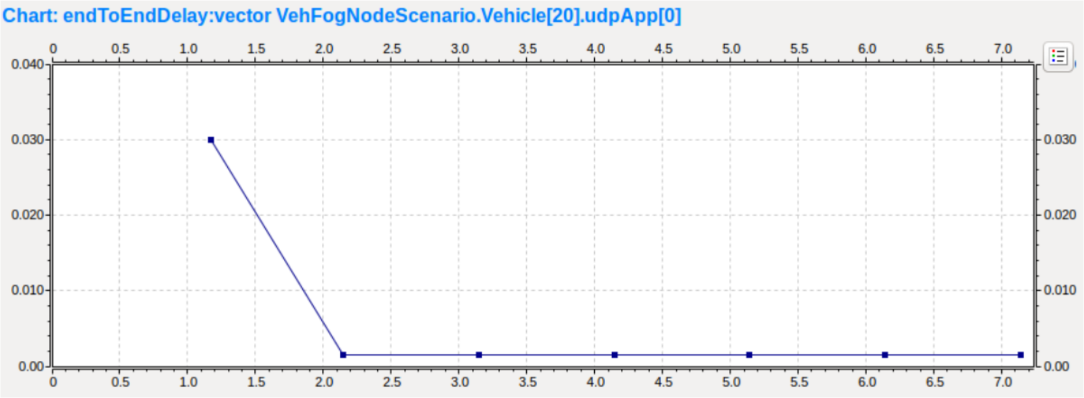


Figure 4.30 – End to end delay.

End to End Delay is seen in the previous graph is also in the first step of simulation is heavy due to the process of beaconing exchanged between all network nodes but the rest of simulation we see that End to End delay is also balanced and there is no latency despite the mobility of nodes and the size of data turning in the network.

Conclusion

In this chapter, we have presented the creation of our model dedicated to simulation of vehicular fog application for video streaming. After the execution of the proposed scenario, we saw that the fog nodes have worked well and improved performance as we seen in the results such as low latency radio state almost steady and its principle is based on five basic steps which are:

- Extraction of sub networks.
- Extraction of links.
- The dominant group calculates.
- The colorization of the nodes.
- Disseminate video packets.

The goal of this strategy is to set up the difference between the different calculus nodes and storage, as well as reduce latency in our video streaming application using fog computing technology.

General conclusion

We recall that the main objective of this thesis is to implement an approach that uses fog computing technology for network traffic control system for vehicular video streaming. This approach includes broadcasting recorded video events from one vehicle to all other vehicles that support the power of computing and communication. After that, the proposal is simulated using the Omnettpp simulation model.

At the beginning, we presented the vehicular networks; their components, their characteristics and various vehicle applications. Then, we describe the different types and strategies of data dissemination in VANET. Finally, we presented the integration of Cloud Computing in VANET networks with the main problems of VANET cloud applications.

We began by discussing vehicular networks, including their components, characteristics, and different vehicle applications. Then, in VANET, we go over the various types and techniques for data dissemination. The integration of Cloud Computing in VANET networks was then described, along with the key issues with VANET cloud applications. Finally, an overview of vehicular fog computing is given.

Then, we mentioned the basic concepts of video streaming, different techniques of video streaming metrics such as quality of service, quality of experience, coding techniques, etc. Then, in order to assure excellent video streaming quality, we present a complete state-of-the-art evaluation of various video streaming works on VANET, including categorization, research, and comparison of these diverse works in terms of different transmission metrics. Our strategy, like the other strategies that have been proposed, our contribution in this area takes into account vehicular fog computing and real-time video streaming application.

In our contribution, we mentioned the relevant problems of video streaming in VANETs. Then, we propose a clustering approach to create virtual clusters for video streaming data dissemination. After that, we show how vehicle fog nodes or virtual clusters play the role of gateway and collaborate in the process of communication and processing. We then present the meta-project model, the organization chart, and the architecture of the model. At the end of the chapter, we present the algorithms implemented in the network.

Finally, in the last chapter, we present our simulation project and the different stages of launching our project and network performance.

Prospects and potential work in the future are:

- Among the disadvantages of radio communication is sending packets to all the nodes. We will try to route the packets to the nodes specific.

- Use Sumo simulator to play real time scenario in real road traffic or urban city environment.

Bibliography

[1] M. R. Ghori, K. Z. Zamli, N. Quosthoni, M. Hisyam, and M. Montaser, "Vehicular ad-hoc network (vanet)," in *2018 IEEE international conference on innovative research and development (ICIRD)*. IEEE, 2018, pp. 1–6.

[2] Y. Qian and N. Moayeri, "Design of secure and application-oriented vanets," in *VTC Spring 2008-IEEE Vehicular Technology Conference*. IEEE, 2008, pp. 2794–2799.

[3] Y. Xie, L. Wu, Y. Zhang, and J. Shen, "Efficient and secure authentication scheme with conditional privacy-preserving for vanets," *Chinese Journal of Electronics*, vol. 25, no. 5, pp. 950–956, 2016.

[4] M. Fahad, F. Aadil, S. Khan, P. A. Shah, K. Muhammad, J. Lloret, H. Wang, J. W. Lee, I. Mehmood *et al.*, "Grey wolf optimization based clustering algorithm for vehicular ad-hoc networks," *Computers & Electrical Engineering*, vol. 70, pp. 853–870, 2018.

[5] C. Campolo and A. Molinaro, "On vehicle-to-roadside communications in 802.11 p/wave vanets," in *2011 IEEE wireless communications and networking conference*. IEEE, 2011, pp. 1010–1015.

[6] S. Al-Sultan, M. M. Al-Doori, A. H. Al-Bayatti, and H. Zedan, "A comprehensive survey on vehicular ad hoc network," *Journal of network and computer applications*, vol. 37, pp. 380–392, 2014.

[7] J. Petit, "Surcout de l'authentification et du consensus dans la securite des reseaux sans fil vehiculaires," Ph.D. dissertation, Universite de Toulouse, Universite Toulouse III-Paul Sabatier, 2011.

[8] S. Zeadally, R. Hunt, Y.-S. Chen, A. Irwin, and A. Hassan, "Vehicular ad hoc networks (vanets): status, results, and challenges," *Telecommunication Systems*, vol. 50, no. 4, pp. 217–241, 2012.

[9] M.-W. Ryu, S.-H. Cha, and K.-H. Cho, "Dsrc-based channel allocation algorithm for emergency message dissemination in vanets," in *International Conference on Hybrid Information Technology*. Springer, 2011, pp. 105–112.

[10] A. M. Vegni and T. D. Little, "Hybrid vehicular communications based on v2v-v2i protocol switching," *International Journal of Vehicle Information and Communication Systems*, vol. 2, no. 3-4, pp. 213–231, 2011.

[11] T. Willke and P. Tientrakool, "& maxemchuk, nf (2009). a survey of inter-vehicle communication protocols and their applications," *IEEE Communications Surveys Tutorials*, vol. 11, no. 2.

[12] P. Papadimitratos, A. De La Fortelle, K. Evenssen, R. Brignolo, and S. Cosenza, "Vehicular communication systems: Enabling technologies, applications, and future outlook on intelligent transportation," *IEEE communications magazine*, vol. 47, no. 11, pp. 84–95, 2009.

[13] F. D. Da Cunha, A. Boukerche, L. Villas, A. C. Viana, and A. A. Loureiro, "Data communication in vanets: a survey, challenges and applications," Ph.D. dissertation, INRIA Saclay; INRIA, 2014.

[14] H. Hartenstein and L. Laberteaux, "A tutorial survey on vehicular ad hoc networks," *IEEE Communications magazine*, vol. 46, no. 6, pp. 164–171, 2008.

[15] E. Schoch, F. Kargl, M. Weber, and T. Leinmuller, "Communication patterns in vanets," *IEEE Communications Magazine*, vol. 46, no. 11, pp. 119–125, 2008.

[16] Y. Toor, P. Muhlethaler, A. Laouiti, and A. De La Fortelle, "Vehicle ad hoc networks: Applications and related technical issues," *IEEE communications surveys & tutorials*, vol. 10, no. 3, pp. 74–88, 2008.

[17] F. Cunha, L. Villas, A. Boukerche, G. Maia, A. Viana, R. A. Mini, and A. A. Loureiro, "Data communication in vanets: Protocols, applications and challenges," *Ad Hoc Networks*, vol. 44, pp. 90–103, 2016.

[18] M. Amadeo, C. Campolo, and A. Molinaro, "Enhancing ieee 802.11 p/wave to provide infotainment applications in vanets," *Ad Hoc Networks*, vol. 10, no. 2, pp. 253–269, 2012.

[19] H. Cheng, H. Shan, and W. Zhang, "Information and road safety service support in vehicular networking: Form a communication perspective," *Mechanical Systtems and Signal Process*, vol. 25, no. 6, 2020.

[20] J. B. Kenney, "Dedicated short-range communications (dsrc) standards in the united states," *Proceedings of the IEEE*, vol. 99, no. 7, pp. 1162–1182, 2011.

[21] D. Jiang and L. Delgrossi, "Ieee 802.11 p: Towards an international standard for wireless access in vehicular environments," in *VTC Spring 2008-IEEE Vehicular Technology Conference*. IEEE, 2008, pp. 2036–2040.

[22] R. Jiang and Y. Zhu, "Wireless access in vehicular environment," *Encyclopedia of Wireless Networks. Dallas: Springer International Publishing*, pp. 1–5, 2019.

[23] F. A. Teixeira, V. F. e Silva, J. L. Leoni, D. F. Macedo, and J. M. Nogueira, "Vehicular networks using the ieee 802.11 p standard: An experimental analysis," *Vehicular Communications*, vol. 1, no. 2, pp. 91–96, 2014.

[24] R. A. Uzcátegui, A. J. De Sucre, and G. Acosta-Marum, "Wave: A tutorial," *IEEE Communications magazine*, vol. 47, no. 5, pp. 126–133, 2009.

[25] A. Jafari, S. Al-Khayatt, and A. Dogman, "Performance evaluation of ieee 802.11 p for vehicular communication networks," in *2012 8th international symposium on communication systems, networks & digital signal processing (CSNDSP)*. IEEE, 2012, pp. 1–5.

[26] Y. Zang, L. Stibor, B. Walke, H.-J. Reumerman, and A. Barroso, "A novel mac protocol for throughput sensitive applications in vehicular environments," in *2007 IEEE 65th Vehicular Technology Conference-VTC2007-Spring*. IEEE, 2007, pp. 2580–2584.

[27] P. Plainchault, "Sécurisation de la conduite par communication véhicule infrastructure à base de transpondeurs," Ph.D. dissertation, 2005.

[28] F. Belarbi, "Les systèmes de communication entre les véhicules et l'infrastructure: leur contribution aux pratiques d'exploitation de la route: Le cas d'une application pour l'information des autoroutes (aida)," Ph.D. dissertation, École nationale des ponts et chaussées (France), 2004.

[29] D. Bektache, "application et modelisation d un protocole de communication pour la securite routiere," Ph.D. dissertation, these de doctorat, universite badji mokhtar annaba, 2014.

[30] P. Bellavista, "Mobile cloud networking: Lessons learnt, open research directions, and industrial innovation opportunities," in *2016 4th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering (MobileCloud)*. IEEE, 2016, pp. 79–80.

[31] Y. Morgan, "Novel issues in dsrc vehicular communication radios," *IEEE Canadian Review Magazine*, 2010.

[32] A. Benaidja, "Echange d'informations en temps reel dans les reseaux de vehicules," Ph.D. dissertation, Sorbonne Paris Cite, 2016.

[33] N. Haddadou, "Reseaux ad hoc vehiculaires: vers une dissemination de donnees efficace, cooperative et fiable," Ph.D. dissertation, Paris Est, 2014.

[34] 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, 2015.

[35] M. A. Al Mamun, K. Anam, M. F. A. Onik, and A. Esfar-E-Alam, "Deployment of cloud computing into vanet to create ad hoc cloud network architecture," in *Proceedings of the world congress on engineering and computer science*, vol. 1, 2012, pp. 24–26.

[36] R. Hussain, J. Son, H. Eun, S. Kim, and H. Oh, "Rethinking vehicular communications: Merging vanet with cloud computing," in *4th IEEE International Conference on Cloud Computing Technology and Science Proceedings*. IEEE, 2012, pp. 606–609.

[37] R. Shrestha, R. Bajracharya, and S. Y. Nam, "Challenges of future vanet and cloud-based approaches," *Wireless Communications and Mobile Computing*, vol. 2018, 2018.

[38] O. N. Fundation, "Software-defined networking: The new norm for networks," *ONF White Paper*, vol. 2, no. 2-6, p. 11, 2012.

[39] O. C. A. W. Group *et al.*, "Openfog reference architecture for fog computing," *OPFRA001*, vol. 20817, p. 162, 2017.

[40] F. Bonomi, R. Milito, P. Natarajan, and J. Zhu, "Fog computing: A platform for internet of things and analytics," in *Big data and internet of things: A roadmap for smart environments*. Springer, 2014, pp. 169–186.

[41] C. Huang, R. Lu, and K.-K. R. Choo, "Vehicular fog computing: architecture, use case, and security and forensic challenges," *IEEE Communications Magazine*, vol. 55, no. 11, pp. 105–111, 2017.

[42] M. L. Sichitiu and M. Kihl, "Inter-vehicle communication systems: a survey," *IEEE Communications Surveys & Tutorials*, vol. 10, no. 2, pp. 88–105, 2008.

[43] K. Bilstrup, E. Uhlemann, E. G. Strom, and U. Bilstrup, "Evaluation of the ieee 802.11 p mac method for vehicle-to-vehicle communication," in *2008 IEEE 68th Vehicular Technology Conference*. IEEE, 2008, pp. 1–5.

[44] What does video streaming mean? https://www.techopedia.com/definition/9927/video-streaming. Accessed: 2021-04-05.

[45] Video streaming. https://www.pcmag.com/encyclopedia/term/streaming-video. Accessed: 2021-04-05.

[46] M. B. Brahim, Z. H. Mir, W. Znaidi, F. Filali, and N. Hamdi, "Qos-aware video transmission over hybrid wireless network for connected vehicles," *IEEE access*, vol. 5, pp. 8313–8323, 2017.

[47] N. Taherkhani and S. Pierre, "Centralized and localized data congestion control strategy for vehicular ad hoc networks using a machine learning clustering algorithm," *IEEE Transactions on Intelligent Transportation Systems*, vol. 17, no. 11, pp. 3275–3285, 2016.

[48] K. Piamrat, C. Viho, J.-M. Bonnin, and A. Ksentini, "Quality of experience measurements for video streaming over wireless networks," in *2009 Sixth International Conference on Information Technology: New Generations*. IEEE, 2009, pp. 1184–1189.

[49] P. ITU-T RECOMMENDATION, "Subjective video quality assessment methods for multimedia applications," *International telecommunication union*, 1999.

[50] R. I.-R. BT, "Methodology for the subjective assessment of the quality of television pictures," *International Telecommunication Union*, 2002.

[51] K. Nahrstedt, "Quality of service in wireless networks over unlicensed spectrum," *Synthesis Lectures on Mobile and Pervasive Computing*, vol. 6, no. 1, pp. 1–176, 2011.

[52] X. Xiao, "Chapter 2 - what is qos?" in *Technical, Commercial and Regulatory Challenges of QoS*, ser. The Morgan Kaufmann Series in Networking, X. Xiao, Ed. Boston: Morgan Kaufmann, 2008, pp. 11–35. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780123736932000021

[53] K. Stuhlmuller, N. Farber, M. Link, and B. Girod, "Analysis of video transmission over lossy channels," *IEEE Journal on selected areas in communications*, vol. 18, no. 6, pp. 1012–1032, 2000.

[54] H. Wu and H. Ma, "Opportunistic routing for live video streaming in vehicular ad hoc networks," in *Proceeding of IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2014*. IEEE, 2014, pp. 1–3.

[55] T. H. Luan, L. X. Cai, and X. Shen, "Impact of network dynamics on user's video quality: Analytical framework and qos provision," *IEEE Transactions on Multimedia*, vol. 12, no. 1, pp. 64–78, 2009.

[56] P. Telagarapu, V. J. Naveen, A. L. Prasanthi, and G. V. Santhi, "Image compression using dct and wavelet transformations," *International Journal of Signal Processing, Image Processing and Pattern Recognition*, vol. 4, no. 3, pp. 61–74, 2011.

[57] K. Brunnström, S. A. Beker, K. De Moor, A. Dooms, S. Egger, M.-N. Garcia, T. Hossfeld, S. Jumisko-Pyykkö, C. Keimel, M.-C. Larabi *et al.*, "Qualinet white paper on definitions of quality of experience," 2013.

[58] M. Elkotob, D. Grandlund, K. Andersson, and C. Ahlund, "Multimedia qoe optimized management using prediction and statistical learning," in *IEEE Local Computer Network Conference*. Ieee, 2010, pp. 324–327.

[59] T. A. Q. Pham, K. Piamrat, and C. Viho, "Qoe-aware routing for video streaming over vanets," in *2014 IEEE 80th Vehicular Technology Conference (VTC2014-Fall)*. IEEE, 2014, pp. 1–5.

[60] Z. Wang, L. Lu, and A. C. Bovik, "Video quality assessment based on structural distortion measurement," *Signal processing: Image communication*, vol. 19, no. 2, pp. 121–132, 2004.

[61] A. Hore and D. Ziou, "Image quality metrics: Psnr vs. ssim," in *2010 20th international conference on pattern recognition*. IEEE, 2010, pp. 2366–2369.

[62] H. Schwarz, D. Marpe, and T. Wiegand, "Overview of the scalable video coding extension of the h. 264/avc standard," *IEEE Transactions on circuits and systems for video technology*, vol. 17, no. 9, pp. 1103–1120, 2007.

[63] Y. Wang, A. R. Reibman, and S. Lin, "Multiple description coding for video delivery," *Proceedings of the IEEE*, vol. 93, no. 1, pp. 57–70, 2004.

[64] K. Psannis and Y. Ishibashi, "Efficient flexible macroblock ordering technique," *IEICE transactions on communications*, vol. 91, no. 8, pp. 2692–2701, 2008.

[65] C. Rezende, M. Almulla, and A. Boukerche, "The use of erasure coding for video streaming unicast over vehicular ad hoc networks," in *38th Annual IEEE Conference on Local Computer Networks*. IEEE, 2013, pp. 715–718.

[66] S. Katti, H. Rahul, W. Hu, D. Katabi, M. Médard, and J. Crowcroft, "Xors in the air: Practical wireless network coding," in *Proceedings of the 2006 conference on Applications, technologies, architectures, and protocols for computer communications*, 2006, pp. 243–254.

[67] L. B. Yuste, F. Boronat, M. Montagud, and H. Melvin, "Understanding timelines within mpeg standards," *IEEE Communications Surveys & Tutorials*, vol. 18, no. 1, pp. 368–400, 2015.

[68] A. Lo, G. Heijenk, and I. Niemegeers, "Evaluation of mpeg-4 video streaming over umts/wcdma dedicated channels," in *First International Conference on Wireless Internet (WICON'05)*. IEEE, 2005, pp. 182–189.

[69] P. Lambert, W. De Neve, Y. Dhondt, and R. Van de Walle, "Flexible macroblock ordering in h. 264/avc," *Journal of Visual Communication and Image Representation*, vol. 17, no. 2, pp. 358–375, 2006.

[70] G. J. Sullivan, J.-R. Ohm, W.-J. Han, and T. Wiegand, "Overview of the high efficiency video coding (hevc) standard," *IEEE Transactions on circuits and systems for video technology*, vol. 22, no. 12, pp. 1649–1668, 2012.

[71] N. Qadri, M. Fleury, M. Altaf, B. Rofoee, and M. Ghanbari, "Resilient p2p multimedia exchange in a vanet," in *2009 2nd IFIP Wireless Days (WD)*. IEEE, 2009, pp. 1–6.

[72] A. Torres, P. Piñol, C. T. Calafate, J.-C. Cano, and P. Manzoni, "Evaluating h. 265 real-time video flooding quality in highway v2v environments," in *2014 IEEE Wireless Communications and Networking Conference (WCNC)*. IEEE, 2014, pp. 2716–2721.

[73] C. I. Paredes, A. M. Mezher, and M. A. Igartua, "Performance comparison of h. 265/hevc, h. 264/avc and vp9 encoders in video dissemination over vanets," in *International Conference on Smart Objects and Technologies for Social Good*. Springer, 2016, pp. 51–60.

[74] P. Piñol, A. Torres, O. López, M. Martinez, and M. P. Malumbres, "Evaluating hevc video delivery in vanet scenarios," in *2013 IfiP Wireless Days (WD)*. IEEE, 2013, pp. 1–6.

[75] M.-F. Tsai, C.-K. Shieh, T.-C. Huang, and D.-J. Deng, "Forward-looking forward error correction mechanism for video streaming over wireless networks," *IEEE Systems Journal*, vol. 5, no. 4, pp. 460–473, 2011.

[76] C.-H. Lin, C.-K. Shieh, and W.-S. Hwang, "An access point-based fec mechanism for video transmission over wireless lans," *IEEE Transactions on Multimedia*, vol. 15, no. 1, pp. 195–206, 2012.

[77] T.-Y. Wu, S. Guizani, W.-T. Lee, and P.-C. Huang, "An enhanced structure of layered forward error correction and interleaving for scalable video coding in wireless video delivery," *IEEE wireless communications*, vol. 20, no. 4, pp. 146–152, 2013.

[78] M.-F. Tsai, C.-H. Ke, C.-I. Kuo, and C.-K. Shieh, "Path dependent adaptive forward error correction with multipath interleaving control scheme for video streaming over wireless networks," in *2009 Fifth International Conference on Intelligent Information Hiding and Multimedia Signal Processing*. IEEE, 2009, pp. 1236–1239.

[79] M.-F. Tsai, C.-K. Shieh, C.-H. Ke, and D.-J. Deng, "Sub-packet forward error correction mechanism for video streaming over wireless networks," *Multimedia Tools and Applications*, vol. 47, no. 1, pp. 49–69, 2010.

[80] P. Bucciol, J. L. Zechinelli-Martini, and G. Vargas-Solar, "Optimized transmission of loss tolerant information streams for real-time vehicle-to-vehicle communications," in *2009 Mexican International Conference on Computer Science*. IEEE, 2009, pp. 142–145.

[81] C. Quadros, A. Santos, M. Gerla, and E. Cerqueira, "Qoe-driven dissemination of real-time videos over vehicular networks," *Computer Communications*, vol. 91, pp. 133–147, 2016.

[82] C. Rezende, R. W. Pazzi, A. Boukerche, and S. Nikoletseas, "The effect of redundancy on video broadcasting in vehicular networks," in *2011 IEEE International Conference on Communications (ICC)*. IEEE, 2011, pp. 1–5.

[83] A. Mammeri, A. Boukerche, and Z. Fang, "Video streaming over vehicular ad hoc networks using erasure coding," *IEEE Systems Journal*, vol. 10, no. 2, pp. 785–796, 2015.

[84] H. Xie, A. Boukerche, and A. A. Loureiro, "A multipath video streaming solution for vehicular networks with link disjoint and node-disjoint," *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 12, pp. 3223–3235, 2014.

[85] ——, "Mervs: A novel multichannel error recovery video streaming protocol for vehicle ad hoc networks," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 2, pp. 923–935, 2015.

[86] S. Xu, H. Zhou, Z. Yu, and S. Zhang, "Simulated study on video communication over vanet," in *World Automation Congress 2012*. IEEE, 2012, pp. 221–225.

[87] The network simulator ns-2. http://www.isi.edu/nsnam/ns/. Accessed: 2021-05-15.

[88] J. Klaue, B. Rathke, and A. Wolisz, "Evalvid–a framework for video transmission and quality evaluation," in *International conference on modelling techniques and tools for computer performance evaluation*. Springer, 2003, pp. 255–272.

[89] http://vanet.eurecom.fr/. Accessed: 2021-05-15.

[90] C. E. Perkins and P. Bhagwat, "Highly dynamic destination-sequenced distance-vector routing (dsdv) for mobile computers," *ACM SIGCOMM computer communication review*, vol. 24, no. 4, pp. 234–244, 1994.

[91] C. E. Perkins and E. M. Royer, "Ad-hoc on-demand distance vector routing," in *Proceedings WMCSA'99. Second IEEE Workshop on Mobile Computing Systems and Applications*. IEEE, 1999, pp. 90–100.

[92] B. Karp and H.-T. Kung, "Gpsr: Greedy perimeter stateless routing for wireless networks," in *Proceedings of the 6th annual international conference on Mobile computing and networking*, 2000, pp. 243–254.

[93] I. Zaimi, Z. S. Houssaini, A. Boushaba, M. Oumsis, and D. Aboutajdine, "An evaluation of routing protocols for vehicular ad-hoc network considering the video stream," *Wireless Personal Communications*, vol. 98, no. 1, pp. 945–981, 2018.

[94] ——, "Vehicular ad-hoc network: Evaluation of qos and qoe for multimedia application," in *International Conference on Networked Systems*. Springer, 2016, pp. 367–371.

[95] T. Honda, M. Ikeda, E. Spaho, M. Hiyama, and L. Barolli, "Effect of buildings in vanets communication: Performance of olsr protocol for video streaming application," in *2013 Eighth International Conference on Broadband and Wireless Computing, Communication and Applications*. IEEE, 2013, pp. 323–327.

[96] P. Jacquet, P. Muhlethaler, T. Clausen, A. Laouiti, A. Qayyum, and L. Viennot, "Optimized link state routing protocol for ad hoc networks," in *Proceedings. IEEE International Multi Topic Conference, 2001. IEEE INMIC 2001. Technology for the 21st Century*. IEEE, 2001, pp. 62–68.

[97] I. Zaimi, Z. S. Houssaini, A. Boushaba, and M. Oumsis, "An improved gpsr protocol to enhance the video quality transmission over vehicular ad hoc networks," in *2016 international conference on wireless networks and mobile communications (WINCOM)*. IEEE, 2016, pp. 146–153.

[98] B. Moussaoui, S. Djahel, M. Smati, and J. Murphy, "A cross layer approach for efficient multimedia data dissemination in vanets," *Vehicular Communications*, vol. 9, pp. 127–134, 2017.

[99] A. Walker and M. Radenkovic, "Gpsr-tars: congestion aware geographically targeted remote surveillance for vanets," in *2017 International Conference on Selected Topics in Mobile and Wireless Networking (MoWNeT)*. IEEE, 2017, pp. 1–6.

[100] C. Quadros, E. Cerqueira, A. Santos, and M. Gerla, "A multi-flow-driven mechanism to support live video streaming on vanets," in *2014 Brazilian Symposium on Computer Networks and Distributed Systems*. IEEE, 2014, pp. 468–476.

[101] F. Granelli, G. Boato, D. Kliazovich, and G. Vernazza, "Enhanced gpsr routing in multi-hop vehicular communications through movement awareness," *IEEE Communications Letters*, vol. 11, no. 10, pp. 781–783, 2007.

[102] F. Xie, K. A. Hua, W. Wang, and Y. H. Ho, "Performance study of live video streaming over highway vehicular ad hoc networks," in *2007 IEEE 66th vehicular technology conference*. IEEE, 2007, pp. 2121–2125.

[103] A. Bradai and T. Ahmed, "Reviv: Selective rebroadcast mechanism for video streaming over vanet," in *2014 IEEE 79th Vehicular Technology Conference (VTC Spring)*. IEEE, 2014, pp. 1–6.

[104] Q. Chen, D. Jiang, and L. Delgrossi, "Ieee 1609.4 dsrc multi-channel operations and its implications on vehicle safety communications," in *2009 IEEE vehicular networking conference (VNC)*. IEEE, 2009, pp. 1–8.

[105] C. Rezende, A. Mammeri, A. Boukerche, and A. A. Loureiro, "A receiver-based video dissemination solution for vehicular networks with content transmissions decoupled from relay node selection," *Ad Hoc Networks*, vol. 17, pp. 1–17, 2014.

[106] C. Rezende, H. S. Ramos, R. W. Pazzi, A. Boukerche, A. C. Frery, and A. A. Loureiro, "Virtus: A resilient location-aware video unicast scheme for vehicular networks," in *2012 IEEE International Conference on Communications (ICC)*. IEEE, 2012, pp. 698–702.

[107] C. Rezende, A. Boukerche, H. S. Ramos, and A. A. Loureiro, "A reactive and scalable unicast solution for video streaming over vanets," *IEEE Transactions on Computers*, vol. 64, no. 3, pp. 614–626, 2014.

[108] C. Quadros, E. Cerqueira, A. Santos, J. Lim, and M. Gerla, "Beacon-less video streaming management for vanets based on qoe and link-quality," in *2015 IFIP/IEEE International Symposium on Integrated Network Management (IM)*. IEEE, 2015, pp. 191–198.

[109] I. Tal and G.-M. Muntean, "User-oriented cluster-based solution for multimedia content delivery over vanets," in *IEEE international symposium on broadband multimedia systems and broadcasting*. IEEE, 2012, pp. 1–5.

[110] G.-M. Muntean, P. Perry, and L. Murphy, "A comparison-based study of quality-oriented video on demand," *IEEE Transactions on Broadcasting*, vol. 53, no. 1, pp. 92–102, 2007.

[111] J. Y. Yu and P. H. J. Chong, "A survey of clustering schemes for mobile ad hoc networks," *IEEE Communications Surveys & Tutorials*, vol. 7, no. 1, pp. 32–48, 2005.

[112] Y. Chen, X. Cai, M. Gao, X. Wang, L. Zhu, and C. Li, "Dynamic overlay-based scheme for video delivery over vanets," in *2014 IEEE 80th Vehicular Technology Conference (VTC2014-Fall)*. IEEE, 2014, pp. 1–5.

[113] M. Asefi, J. W. Mark, and X. S. Shen, "A mobility-aware and quality-driven retransmission limit adaptation scheme for video streaming over vanets," *IEEE Transactions on Wireless Communications*, vol. 11, no. 5, pp. 1817–1827, 2012.

[114] R. An, Z. Liu, and Y. Ji, "Svc-based video streaming over highway vehicular networks with base layer guarantee," in *2017 IFIP/IEEE Symposium on Integrated Network and Service Management (IM)*. IEEE, 2017, pp. 1168–1173.

[115] E. Belyaev, S. Moreschini, and A. Vinel, "Uncoordinated multi-user video streaming in vanets using skype," in *2017 IEEE 22nd International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*. IEEE, 2017, pp. 1–3.

[116] https://www.skype.com/en/. Accessed: 2021-05-16.

[117] P. Bezerra, A. Melo, A. Douglas, H. Santos, D. Rosário, and E. Cerqueira, "A collaborative routing protocol for video streaming with fog computing in vehicular ad hoc networks," *International Journal of Distributed Sensor Networks*, vol. 15, no. 3, p. 1550147719832839, 2019.

[118] T. K. Refaat, B. Kantarci, and H. T. Mouftah, "Virtual machine migration and management for vehicular clouds," *Vehicular Communications*, vol. 4, pp. 47–56, 2016.

[119] O. Osanaiye, S. Chen, Z. Yan, R. Lu, K. K. R. Choo, M. Dlodlo *et al.*, "From cloud to fog computing," 2017.

[120] A. M. Vegni and E. Natalizio, "Forwarder smart selection protocol for limitation of broadcast storm problem," *Journal of Network and Computer Applications*, vol. 47, pp. 61–71, 2015.

[121] C. Zhu, G. Pastor, Y. Xiao, and A. Ylajaaski, "Vehicular fog computing for video crowdsourcing: Applications, feasibility, and challenges," *IEEE Communications Magazine*, vol. 56, no. 10, pp. 58–63, 2018.

[122] H. M. A. Fahmy, *Wireless sensor networks: concepts, applications, experimentation and analysis*. Springer, 2016.

[123] K. Wehrle, M. Günes, and J. Gross, *Modeling and tools for network simulation*. Springer Science & Business Media, 2010.

[124] Inet users guide. https://inet.omnetpp.org/docs/users-guide/. Accessed: 2021-06-25.

[125] A. Núñez, J. L. Vázquez-Poletti, A. C. Caminero, G. G. Castañé, J. Carretero, and I. M. Llorente, "icancloud: A flexible and scalable cloud infrastructure simulator," *Journal of Grid Computing*, vol. 10, no. 1, pp. 185–209, 2012.