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MASTER'S THESIS
Data Scheduling For Vehicular Fog Computing

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Abstract

The Vehicular Adhoc NETworks (VANET) have become a crucial research area in transportation systems, thanks to technological development, in recent years. These networks generally consist of fixed nodes named Road Side Units (RSU) and mobile nodes (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. Indeed, these services are hosted in 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 leads at road events and frequent packets loss. The aim of this thesis is subscribed in the context of Vehicular Fog Computing (VFC) applications. Although video streaming is the most supported application on driving and the most network sensitive application, we select the video streaming application for our study. We propose a video data scheduling approach 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 Omnett ++ simulator. The network performance of the proposal showed that the simulation was a precise model and that the best virtual fog nodes for the broadcast request and the video event.

KEY WORDS : VANET (Vehicular adhoc network), CC (Cloud Computing), FC (Fog Computing), QoS (Quality Of Service), QoE (Quality Of Experience), VFC (Vehicular fog computing),

Résumé

Les Véhicules Adhoc NETworks (VANET) sont devenus un domaine de recherche crucial dans les systèmes de transport, grâce au développement technologique, ces dernières années. Ces réseaux se composent généralement de nœuds fixes nommés Road Side Units (RSU) et de nœuds mobiles (véhicules). L'objectif principal est d'assurer un niveau fiable de sécurité routière et un confort aspect du voyage. Avec l'évolution des capacités Internet, les véhicules sont devenus plus intelligent sur la route, où une nouvelle gamme d'applications modernes est apparue la forme de communication, de gestion et de contrôle. Ces services permettent aux véhicules de communiquer et diffuser des informations sur la sécurité par le biais de messages. En effet, ces services sont hébergés dans une infrastructure moderne conçue pour la communication comme le cloud l'informatique. Cette convergence conduit à l'apparition de nouveaux paradigmes liés aux véhicules, à savoir le Vehicle Cloud Computing (VCC) et le Vehicle Fog Computing (VFC). Malgré ces avancées, la diffusion des 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, des changements fréquents de topologie et la forte densité de véhicules, ce qui conduit à des événements routiers et perte fréquente de paquets. Le but de cette thèse s'inscrit dans le cadre de Vehicle Applications de calcul de brouillard (VFC). Bien que le streaming vidéo soit le plus pris en charge l'application sur la conduite et l'application la plus sensible au réseau, nous sélectionnons la vidéo application de streaming pour notre étude. Nous proposons une approche de planification des données vidéo basée sur sur la création de réseaux virtuels. Ce réseau virtuel est un sous-ensemble (cluster) des nœuds se connecter les uns aux autres pour obtenir un routage efficace des informations pour le streaming vidéo paquets. Ce mécanisme s'adapte au changement de topologie et à la grande mobilité des nœuds. Au stade de l'évaluation, nous simulons les performances de ce mécanisme à l'aide d'un Simulateur Omnett ++. Les performances réseau de la proposition ont montré que la simulation était un modèle précis et que les meilleurs nœuds de brouillard virtuels pour la demande de diffusion et l'événement vidéo.

ملخص

أصبحت الشبكات المخصصة للمركبات منطقة بحث حاسمة في أنظمة النقل ، وذلك بفضل التطور التكنولوجي في السنوات الأخيرة. تتكون هذه الشبكات بشكل عام من العقد الثابتة المسماة وحدات جانب الطريق والعقد المتنقلة (المركبات). الهدف الرئيسي هو ضمان مستوى موثوق به للسلامة على الطرق وجانب مريح من السفر. مع تطور إمكانات الإنترنت ، أصبحت المركبات أكثر ذكاءً على الطريق ، حيث ظهرت مجموعة جديدة من التطبيقات الحديثة في شكل اتصالات وإدارة وتحكم. تسمح هذه الخدمات للسيارات بالاتصال ونشر معلومات السلامة من خلال الرسائل. في الواقع ، يتم استضافة هذه الخدمات في بنية تحتية حديثة مصممة للاتصالات مثل الحوسبة السحابية. يؤدي هذا التقارب إلى ظهور نماذج جديدة مرتبطة بالمركبات ، وهي الحوسبة السحابية للسيارات وحوسبة الضباب في 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 والتغيرات المتكررة في الطوبولوجيا والكثافة العالية للمركبات ، مما يؤدي إلى حوادث الطرق والحزم المتكررة خسارة. الهدف من هذه الرسالة مشترك في سياق تطبيقات حوسبة الضباب للسيارات . على الرغم من أن دفق الفيديو هو التطبيق الأكثر دعمًا للقيادة والتطبيق الأكثر حساسية للشبكة ، إلا أننا نختار تطبيق دفق الفيديو لدراستنا. نحن نقدم نهج جدولة بيانات الفيديو على أساس إنشاء شبكات افتراضية. هذه الشبكة الافتراضية عبارة عن مجموعة فرعية (مجموعة) من العقد المتصلة ببعضها البعض لتحقيق توجيه فعال للمعلومات الخاصة بحزم بث الفيديو. تتكيف هذه الآلية مع التغيير في الطوبولوجيا والحركة العالية للعقد. في مرحلة التقييم ، نقوم بمحاكاة أداء هذه الآلية باستخدام محاكي.

وأظهر أداء الشبكة للاقتراح أن المحاكاة كانت نموذجًا دقيقًا وأن أفضل عقد الضباب الافتراضية لطلب البث وحدث الفيديو .

الكلمات الرئيسية: (شبكة المركبات المخصصة) ، (الحوسبة السحابية) ،(حوسبة الضباب) ، (جودة الخدمة) ، (جودة الخبرة) ، (حوسبة الضباب للسيارات) .

DEDICATION

To my father, to my mother

To my brother, to my sisters

To my Friends

To My Supervisor Dr. Sahraoui Abdellatif

THANKS

First of all, praise to God who, with his grace, does good works.

My thanks go first of all to Almighty God for the will, the health and patience that gave me during the work period.

To my dear Father

To my dear father, God saved you and made you an asset and a pride for us. Nothing may be enough for you. Thank you Father.

To my dearest mom

No act or expression can express my feelings towards you, that gods you keep for us mom. Thanks Mom

To my brother Abd El nour.And my sisters Abir , Ghoufrane

To my family ,

You are Parents and Brothers, A word of thanks not enough. And cannot be enough. Thank you.

To all my friends,

I am aware it is a big challenge for you all to be on my side, but you never mention it. I'm so thankful!

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Global Introduction

In recent years, the automotive industry has experienced great development and vehicles are no longer called as mechanical systems controlled by certain electronic components. Vehicles have been made smarter and fully connected by offering new features to understand their environment and communicate with other vehicles.

The objective was to process this information and make decisions in real time concerning modern vehicles equipped with cameras, GPS, radar and on-board sensors and wireless communication devices which allow vehicles to communicate with each other via the communication between vehicles (V2V) or with road units via V2I communications (between vehicles and infrastructure).

Among the applications that have aroused great interest from researchers in recent years, those that have exchanged information to ensure road safety, achieve greater reliability by disseminating information over the network. This information concerns congestion conditions, events, accidents, card information. etc. On the other hand, provide a set of functions to ensure a level of comfort when traveling, in terms of knowledge, Internet access, online payment, games, etc.

To be able to support such applications, a network between these vehicles must be created. In which the main interests of these applications, the improvement of road safety, the dissemination of information, traffic avoidance. To achieve a high level of road security, these networks have become an active area of research and are characterized by the emergence of communication and development standards which are constantly increasing. For many vehicle applications such as augmented reality (AR) techniques, autonomous driving, high resolution video streams, etc. These novel applications requiring an amount of resources and higher performances in terms of communication, calculation and storage. Shifting traffic data to the cloud for processing is not possible due to the high latency caused by the round trip between vehicles and the cloud. IT fog, which focuses on moving IT resources to the edge of networks, complements cloud computing to resolve latency constraints and for incoming traffic to the cloud. Regarding fog calculation needs, it is necessary to deploy sufficient computing and communication capacity at the edge of networks, such as LTE base stations, vehicle fog calculation focused 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.

The CC 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 fog computing is a new paradigm invented as an extension of services beyond cloud computing. The Fog operations contains a decentralized environment based on location information and provides traffic services near to vehicles, namely data processing and the storage opportunities. The IT fog paradigm allows access only to local servers for computing purposes, which has reduced latency and performance issues, making it more powerful and well organized.

The main aim of these thesis is subscribed in the context of Vehicular Fog Computing paradigm, In which, this convergence leads to a data scheduling strategy for the application of video streaming in a vehicle fog environment by integrating an approach of clustering . In particular, we proposed an algorithm which 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 aim to reduce latency problem experienced during high internet traffic and the rise of autonomous vehicles and meet the demands of real time applications.

The work presented in this thesis is organized into four chapters as follows:

In chapter, one we will introduce of the concept of vehicular network and the problem of the data dissemination in these networks, mentioning their definition, it's components, it's characteristics, the architectures and the different applications developed in this context. Then the integration of CC and IT fog services in VANETs and the convergence to Vehicular Fog Computing (VFC) paradigm.

In the next chapter, we will show the basic concepts of the video streaming such as: video streaming metrics, video encoding techniques and video compression standards.

In chapter three, we will show the viability of vehicular fog computing in video streaming by adding an approach of clustering based on virtual fog nodes.the proposal use two algorithms , dominant set and intermittent set network .The Vehicles that use the proposed approach can cooperate with each other to stream video traffic and provide visual information about the area being monitored with great precision and high quality.

In chapter four, we will highlight the simulation of the proposal in omnet++ for describing a specific scenario for the video streaming. Then we will discussed the obtained results.

Chapter 1

Introduction on Vehicular Ad-hoc Network

1.1 Introduction

Vehicular networks (VANET) are a special class of Adhoc mobile networks. These networks are characterized by communication limitations, high node mobility and rapid change in typologies. Unlike other mobile networks, VANETs do not have energy constraints, which allows efficient data dissemination and a greater amount of data to collect. 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 purpose of this chapter is to learn the concept of vehicular network and the problem of the 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).

1.2 Vehicular Ad-hoc Network (VANET)

1.2.1 VANET Definition

The VANET is a subclass of Mobile Ad-hoc Networks (MANET). In which, the vehicles are equipped with on-board units, sensors and vehicular systems. The vehicles communicate with each other using Vehicle-To-Vehicle (V2V) and Vehicle-To-Infrastructure (V2I) models. The vehicular networks pro mess a solutions for the traffic control, safe lives and minimize the number of accidents in the roads between vehicles operated in the network without infrastructure; each network node react as gateway node. In a vehicular network, the nodes behaves as smart vehicles.[51]

1.2.2 Vehicular Ad-hoc Network COMPONENTS

TA Trusted Authority

Say CA (trusted authority). It is a source of authenticity of information.It manages and registers all entities on the network (RSU and OBU). MT is supposed to know all the real identities of the vehicles and if necessary disclose them for law enforcement. Also, the TA in certain works takes care of the delivery and the attribution of communications certificates.[53]

RSUs (Road Side Unit)

These entities are TA subordinates. They are installed across the roads. They can be mainly, traffic lights, lampposts or others. Their main responsibility is to support the TA in traffic and vehicles management. They act like access points to the network and and other traffic information.[51]

OBU (On-Board Unit)

These are on-board units in smart vehicles, they bring together a whole high-tech hardware and software components (GPS, radar, cameras, various sensors and others). Their roles are to ensure localization, reception, computation, storage. and sending data over the network. These are transceivers that provide the connection from vehicle to network.[51] [61]

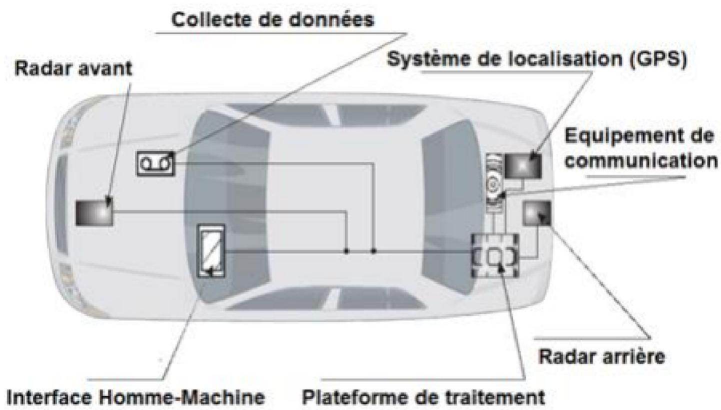


Figure 1.1: Referent element constituting the vehicle

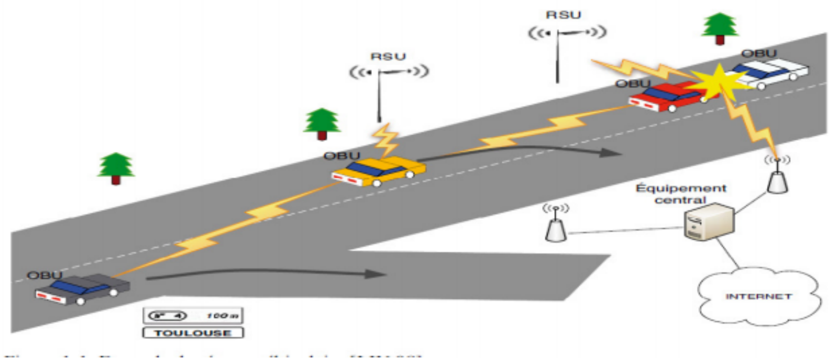


Figure 1.2: Example of vehicle network[61]

The difference from traditional wireless networks where the energy constraint represents a important limited factor, vehicle network entities have large capacities energy they get from the vehicle's power system

1.2.3 The communication environment and the mobility model

Vehicular networks require greater environmental diversity to be taken in 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

1.2.4 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 multiplicity recipients. The broadcast or Multi cast transmission model is therefore called dominate widely in vehicle networks,

1.2.5 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 ever-increasing 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 potential size of vehicular networks is therefore a major characteristic of take into account in the design of these networks.

1.3 VANET Applications

The main applications of VANET networks can be classified into three categories[45]

1.3.1 Road traffic management applications

Traffic management applications focus on improving traffic conditions which aim of reducing traffic congestion and risk of accidents. They provide drivers with technical support allowing them to adapt their route to the situation of road traffic. These applications aim to balance vehicle traffic on the roads for efficient use of the capacity of roads and crossroads and therefore reduce loss of life, travel time and energy consumption ... etc.

1.3.2 Comfort applications

this category includes all applications that contribute to driver comfort which are not part of traffic management or road safety. These applications are present as services provided to the driver. Among these applications are:

local billboards: commercial such as restaurant offers, presence of nearby service stations, or cultural as tourist information relating to the vehicle location.

Another type of comfort app is entertainment communication. An offer from Internet connection on board with video on demand is a perfect example. In addition to all these applications, there is also point-to-point communication between two drivers traveling together. They can exchange messages or share data (video, music, routes, network games). The lives of users can also be facilitated by the remote control of the vehicle electronically (verification of the license drive, technical control, license plate) for the competent services (police, customs, gendarmes).

1.3.3 Road traffic safety applications

They aim to improve passenger safety on the roads by notifying vehicles of any dangerous situation. These applications are generally based on a broadcast, periodic or informative messages allowing drivers to have a knowledge of the state from the road and neighboring vehicles. Widespread examples of services in this category applications are, collision warning, warnings on the conditions of the road, passing and changing lane assistance, etc.

1.4 Vehicular network architectures

In VANETs, we mainly find the fixed nodes that constitute the infrastructure (RSU and TA) and the mobile nodes (vehicles). To be able to exchange various information and data related to the safety and comfort of road users, these different entities must establish communications between them. For this reason, we distinguishes three types of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure communications(V2I) and Hybrid [32].

1.4.1 Vehicle to Vehicle Communications (V2V)

In this approach, a network of vehicles is seen as a special case of MANET (Mobile Ad hoc Network) or energy, memory constraints and computing capacity are relaxed, and or the mobility model is not random, but predictable (underlay of the road network) with very high mobility. This architecture can be used in alert dissemination scenarios (emergency braking, collision, deceleration, etc.) or for cooperative driving. Indeed, in the context of these applications road safety networks show their limits, especially in terms of deadlines. And it is clear that an ad hoc multi-hop communication is more efficient than a communication through an operator network [32].

1.4.2 Vehicle to Infrastructure Communications (V2I)

The architecture (V2I) is made up of RSUs, which the vehicles access for safety, management and comfort applications. RSUs are administered by one or more public bodies or by motorway operators. A vehicle that informs the service road network about an obstacle is an example of V2I communication. In this example, the communication is one-way, from OBU to RSU. We are talking about I2V in the case of Infrastructure-to-Vehicle communication. A sign signaling device equipped with an RSU which sends information to vehicles passing nearby is an example of I2V communication. In the following, by V2I, we include all Vehicle-Infrastructure communications, regardless of the direction of data traffic [32]

1.4.3 Hybrid communication

The combination of these two types of communication architecture makes it possible to obtain an interesting hybrid architecture. 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. However, inter-vehicle communications suffer from routing problems during long distance transmission. In such situations, access to infrastructure can improve network performance. We therefore understand the complementary of the two types of communication and the interest of a hybrid architecture [5].

A special case of hybrid architecture is the VSN (Vehicular Sensor Network). Indeed, this type of network is emerging as a new architecture for vehicle networks. VSN's objective is to collect and proactively disseminate data relating to the environment in which vehicles operate in real time, particularly in urban areas. Cars are increasingly fitted with sensors of all categories (cameras, pollution sensors, rain sensors, tire condition sensors, ESP, ABS, satellite geo-location, etc.). The information provided by this equipment can be useful for obtaining reports on road traffic (traffic jams, slowdowns, average traffic speed, etc.), on available parking spaces, for more general information such as consumption. average fuel and pollution rate, or for surveillance applications (thanks to on-board cameras on vehicles).

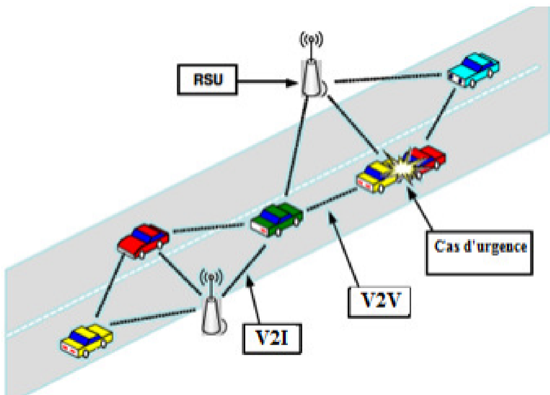


Figure 1.3: Types of communication in a vehicle network[25]

1.5 Communication standards and protocols in VANET

1.5.1 Dedicated Short Range Communications (DSRC)

The U.S. Federal Communication Commission (FCC) allocated a 75 MHz in the 5.850 GHz to 5.925 GHz of DSRC spectrum at 5.9 GHz in 1999 for V2V and V2I communications. The DSRC band is structured into 7 channels of 10 MHz (Ch 172, Ch 174, Ch 176, Ch 178, Ch 180, Ch 182 and Ch 184). The Channel 178 is a control channel (CHH), which is reserved only for the safety applications. The Channels 172 and 184 are reserved for specific use (critical safety of life and high power public safety). The rest of channels (SCH) are served for safety and non-safety applications. Figure 1.4 shows DSRC spectrum band for VANET allocated by FCC. Historically, American Society for Testing and Materials standardization company (ASTM) proposed the first ASTM-DSRC standard (published under the nomination ASTM E2213-03), which is based on IEEE 802.11a standard at the physical layer level, and IEEE 802.11 at MAC layer level, in accordance with DSRC technology. After that, IEEE defines a new family of protocols named IEEE 802.11p, which is based on IEEE 802.11 and ASTM E2213- 03. In IEEE 802.11p, the physical layer and the MAC layer were modified in order to support the wireless communication in vehicular networks. Then, IEEE defines the Wireless Access in Vehicular Environments (WAVE), which defines the protocols at each layer level of the OSI model, to support the wireless vehicular communication.

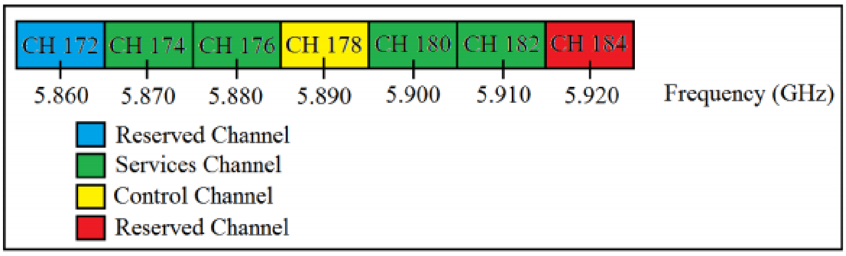


Figure 1.4: DSRC spectrum band for VANET allocated by FCC

!h

1.5.2 Wireless Access in Vehicular Environments (WAVE)

WAVE is a VANET communication technology, which based on IEEE 802.11p and IEEE P1609 standards. The physique (PHY) and MAC layers of WAVE model employ IEEE 802.11p and the other layers of WAVE employ IEEE P1609. The MAC layer employs also IEEE P1609.4 standard. The WAVE architecture is given by figure 1.5.

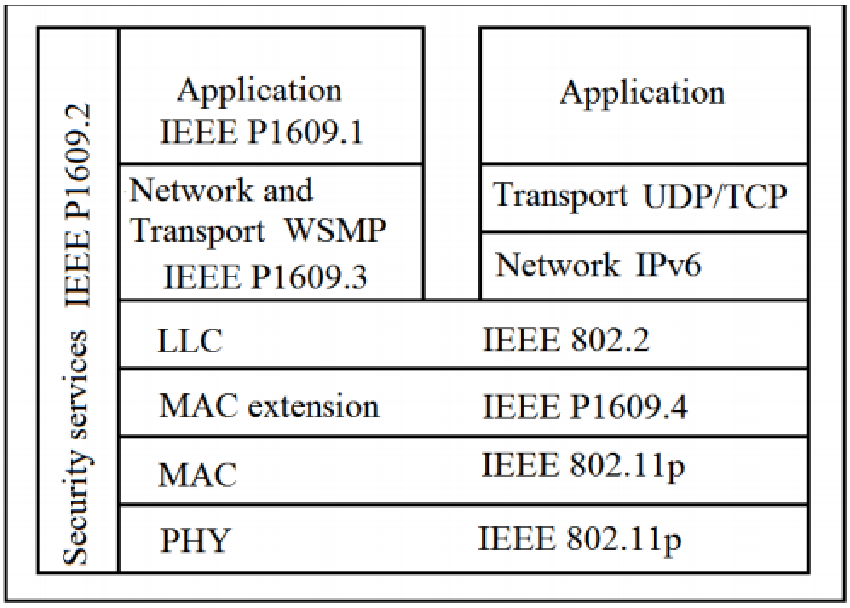


Figure 1.5: WAVE architecture

IEEE 802.11p

IEEE 802.11p is an extension standard of IEEE 802.11 for V2V and V2I communications in VANETs networks to support Intelligent Transportation Systems (ITS) applications. IEEE 802.11p is a modified version of IEEE 802.11a that uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) as the basic medium access scheme at MAC layer level and DSRC technology at PHY layer level. The sending data rate in IEEE 802.11p is ranging from 3 to 27 Mbps over 10 MHz bandwidth, unlike IEEE 802.11a in which it operates with 20 MHz bandwidth [18].

IEEE P1609

IEEE P1609 is a set of standards (P1609.1, P1609.2, P1609.3 and P1609.4) used by the higher layers of WAVE.

IEEE P1609.1

standard[38] is responsible for the resource management including its services, interfaces, and protective mechanisms for security and privacy. According to this standard, OBU and RSU have three components: Resource Management Applications (RMAs), Resource Manager (RM) and Resource Command Processor (RCP). The first one represents the applications that run at the OBU computer and which requests the resources of other OBUs. The second one is the intermediate component considered as a broker between RMAs and RCP. The latter component executes the RMAs commands received via RM[49].

IEEE P1609.2

IEEE P1609.2 standard[39] provides the security services such as confidentiality, authenticity, integrity and anonymity for applications and management messages. This standard defines also the format of secure messages and their processing method.

IEEE P1609.3

IEEE P1609.3 standard[40] defines the protocols and functions mainly at network and transport layers. The WAVE network services can be divided into two parts: data-plan services and management-plan services [1]. The former supports the protocols IPv6 and WSMP in order to transmit a Wave Short Message (WSM). The latter is known as WAVE Management Entity (WME) and it responsible for the system configuration and maintenance.

IEEE P1609.4

IEEE P1609.4 standard [41] provides some functions to enhance the IEEE 802.11p at MAC layer level in order to increase the communication capacity of the vehicle and support the multi-channel operations. In IEEE P1609.4, a synchronized channel coordination scheme based on the Universal Time Coordinated (UTC) was developed to solve the multi-channel coordination problem [65]. UTC is based on the dividing of channel time into synchronized intervals with a fixed length, each interval time is used by an application service to the transmission of messages through this channel

1.6 Communication techniques

Two types of communications are distinguished:

1.6.1 Radio communications

A communication system includes all the elements capable of transmit information (sound, computer data, video, etc.) from one source to one or more destinations. Since the birth 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. [46]

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 RDS-TMC can receive messages at a rate of 20 per minute. This communication mode is suitable for medium distance links (from 10 to 100 km)[17].

The DAB (Digital Audio Broadcasting) system: 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)[5].

The DVB (Digital Video Broadcasting) system: The specifications of the DVB standard define a set of means enabling the dissemination of all types of data, accompanied information about them on all types of media [6].

1.6.2 Wireless communications [5]

Wireless communications technologies are in full development. Among the technologies used in inter-vehicle communications, we can cite:

• Systems that re-use existing infrastructure, 2G cellular systems to 3G and other developments (GSM, GPSR, 3GPP...).

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

802.11 (Wifi), IEEE 802.16 (Wi-MAX) and 802.11p (DSRC). Wireless communication in the vehicle environment is based on two equipment entities: the first is a device installed on critical sections around the infrastructure (stop, intersections...), And the second is that found on board the vehicle.[63]

1.7 Introduction to the dissemination of messages

1.7.1 Dissemination

The dissemination of messages in the vehicular networks consists in 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 short time.

1.7.2 Types of message

The nodes that forming a vehicular wireless network will generate and exchange messages. Depending on the application and the environmental context, a vehicle can send (or receive) a control, alert or other message.[45]

Control message

The control message is generated at regular intervals. Conventionally, each vehicle emits a control message every 100 ms. This message, also called beacon, contains the position, speed, direction and route of the transmitting vehicle. Thanks to the messages control, each vehicle creates a local view of its neighborhood. The vehicle can also predict and anticipate accident or congestion situations. 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

Alert message

The alert message is generated when an event is detected. This can be the detection accident, obstacle, or receiving another alert message. The alert message must be issued at regular intervals to ensure the sustainability of the alert. 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.

Other messages

This type of message contains all messages that are not alert or warning messages. control. These messages are generally not repeated at regular intervals. Indeed, this for example, a financial transaction message or sending 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.

1.7.3 Dissemination Types

There are two types of dissemination: [7]

Dissemination for comfort applications Comfort applications consume a large amount of bandwidth at because of types of applications provided. For example, messaging, downloading files, online games, etc. So you have to optimize the bandwidth, also content of messages can be dynamic and modifiable during transmission of knot to another.

Dissemination for emergency messages Road safety applications make the road more secure, protocols of dissemination must take into account the constraints of sending messages 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.)

1.7.4 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 in VANETs networks, because it requires no information about the vehicles surrounding the transmitter, each recipient vehicle receive 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.[21]

Probabilistic Vehicles using this approach use their knowledge, history, and data collected on the location and mobility of other network nodes for communicate with other vehicles. The objective of this approach is to minimize the number of messages broadcast between two vehicles before choosing the route dissemination of information.

Geographical Each message containing 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 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 send time. This approach can notably warn vehicles who are threatened with a probable accident in a way using these coordinates geographical.

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.

Message priority oriented To ensure the quality of service of the applications supplied in the VANETs, it there are solutions which propose an adaptation to the dissemination of information which is based on the importance of information carried in the message exchanged. To avoid automatic deletion of messages in the event of a collision.

1.8 The convergence of VANET applications to VANET Cloud Services

1.8.1 Cloud Computing

Cloud Computing is a network access model aimed at sharing a large number of IT resources in a transparent and ubiquitous manner. These are rented by a service provider to digital customers, usually via the Internet.[7] Cloud computing is considered an economic model rather than a technology, the authors carried out a survey on the state of the art by answering the question of whether cloud computing will stay or if it is 'one of the passionate subjects that will inevitably be forgotten in the coming years. Most players in the technology market such as Google, Amazon and Microsoft are accelerating their pace in cloud computing by providing services to their users.[8]

1.8.2 Combination of VANET and Cloud Computing

VANETs vehicle network architectures, either V2V or V2I is the most reliable and secure system for effective communication and control traffic. Considering the nature of data dissemination, several paradigms and communication sessions, the creation of a VANET network according to modern needs can be difficult. In MANETs, the nodes organize themselves to create a network without the support of an infrastructure for example (RSU). So CC is supposed to be a new solution to deal 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. The concept of CC was born from the awareness that instead of investing in infrastructure, companies may find it useful to rent the infrastructure and sometimes the software necessary to run their applications. One of the main advantages of cloud computing is its scalable access to IT resources and services [34]

1.8.3 Using Clouds in VANETs

In the VANET network, CC can be used as a network as service (NaaS). Not all cars on the road have access to the Internet. In NaaS, vehicles with Internet access can offer excess capacity, upon request, to other vehicles. It is clear that many drivers will have a permanent Internet connectivity via cellular networks and other access points fixed on the road while driving. Although some cars do not have Internet access, they will have to use the Internet. In such circumstances, each driver having of an Internet connection who wishes to share this resource will announce this information to all vehicles around it.

Or storage as a service (SaaS), in SaaS mode, vehicles with large storage capacity share the storage with other vehicles needing a storage capacity for temporary application.[34]

1.8.4 VANET Cloud architectures

The VANET Clouds are divided into three main architectures, namely the Vehicle Clouds (CVs), Vehicles Using Clouds (VuC) and Clouds hybrid vehicles (HVC), each section will be developed in the subsections next:[23]

Vehicular Clouds (VC)

VC is formed in the following manner. First, the vehicles initiate a protocol for selecting one or more brokers among them and identifying the limits Clouds by selecting an Authorized Entity (EA) among brokers to request authorization to create a cloud. Once the nodes and AE have been chosen. AE invites the vehicle nodes located in the premises of the Cloud boundary to participate in the cloud. Interested vehicles will respond with an acknowledgment. If the number of interested vehicles exceed a certain threshold, AE will ask the higher authorities authorization to create a cloud and provide potential resources. Once authorization obtained, cloud participants will pool their resources to form a rich virtual environment. AE sends calendar to authorities and obtains the authorization for implementation. Note that the work in progress may be entrusted to the Cloud by higher authorities in exchange for certain incentives offered to participants. AE dissolves the cloud when the job is done. [23]

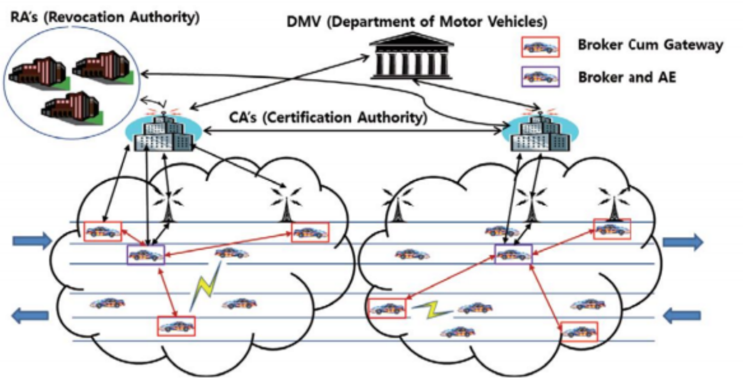


Figure 1.6: Vehicular Clouds[23]

VANET using Clouds (VuC)

Figure 1.6 describes the VuC architecture where VANET uses cloud services moving. The virtualization layer is provided by the gateways. Note that RSUs act as gateways for vehicles to cloud services. The high speed wired communication can be used from PSUs to cloud services. As described in the VANET cloud taxonomy, the services offered by VuC include real-time traffic information and a system multimedia information. [23]

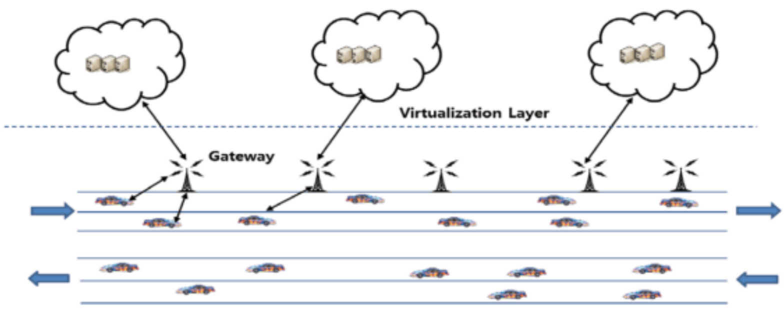


Figure 1.7: VANET using Clouds[23]

1.8.5 VANET Cloud applications

Remote Configuration and Car Performance Checking

Using cloud technology, a car can be monitored and debugged remotely. This technology has already been implemented by a well-known automotive company, Hyundai, which monitors its cars right from the assembly line. The performance of the car are checked remotely by constantly receiving data from the car and are used to provide quality services to customers. However, the user and location privacy is a major concern for such approach.[8]

Big traffic data analysis

Vehicles generate a large amount of traffic data. Through example, tag messages produce data on a millisecond scale, which are invaluable for the services provided by VANET. Storage and processing of data would require a large amount of storage and computing resources. These data could be used for a variety of purposes, ranging from traffic information to entertainment.[8]

With the development of automobile technologies, vehicles are expected to be not only safer, but also greener, more comfortable and entertaining, while self-driving is also a defining requirement of future vehicles. As a promising technology to meet such expectations, vehicular communication networks (VANETs) enable automobiles to communicate with each other through vehicle-to-vehicle (V2V) communication and the network through vehicle-to-infrastructure (V2I) communication, and exchange information efficiently and reliably through the V2V and V2I communications, or more generally, vehicle-to-everything (V2X) communications. VANETs can facilitate a variety of useful applications, such as road safety enhancement, traffic management, vehicular mobile data services, and self-driving assistance [14],[13]

Due to the ever-increasing demand of mobile services and the fast development of self-driving technologies, the data volume required, generated, collected, and transmitted by VANETs has seen an exponential escalation, which is known as big data [31]. As explained in [4], the data in VANETs can well match the "5Vs" of big data characteristics, that is, volume, variety, velocity, value, and veracity, which justifies that VANETs data can be treated as big data and can be solved by big data techniques.

Smart location-based advertisements

With the advent of intelligent vehicles, the billboards located in roadside may be replaced by an advertising system in the car, in which drivers can get announcements of their interest based on their choice. As noted above, location data, driving style and driver location requests would allow the decision servers in the cloud to intelligently announce events and / or places to users, according to their interests.[8]

Vehicle Witnesses

Recently, a researcher proposed a witness vehicle solution (VWaaS) which leverages cloud infrastructure to back up court data original in the event of an incident on the road. When detecting an event or the instruction of the authorities, the vehicles take pictures of the site of interest and send it to the cloud. Cloud infrastructure saves these images as forensic evidence and later provides forensic information to law enforcement, justice and / or insurance agencies.[8]

1.8.6 Vanet Cloud Problems and Challenges

VANETs by using the cloud to solve a lot of existing problems, there are still some fundamental challenges and issues that need to be resolved along with the growth in the number of smart cars and autonomous vehicles.some key challenges and requirements of future VANETs are identified. Future VANETs and its applications progressed over time and integrate with new emerging new technologies, which introduce new functionalities. Some of the key challenges of the future VANETs are seen as next:

Intermittent connectivity Controlling and managing network connection of vehicles and infrastructure is a key that challenging. The intermittent connections and latency caused by high mobility of vehicles or high packet loss rate in vehicular networks must be decreased and avoided .

High mobility and location awareness future vehicles require high mobility and location awareness of the vehicles collaborating in communication. Each vehicle should known the correct position of other vehicles in the same network to cooperate with each others on emergency situation and event detection.

Heterogeneous vehicle management In the near future, there will be a huge number of heterogeneous smart vehicles. the control of heterogeneous vehicles and their sporadic connections is another challenge of future internet of vehicles.

Security The risk to the privacy of user's data content and location is always challenging. the vehicles communicating with each others V2V or with infrastructure V2I should allow users to decide what kind information should be exchanged and what should be kept private. It's easy to assure Privacy by examining sensitive data locally, instead of sending it to the cloud data center for analysis.

Support of network intelligence: One of the most challenges of future vehicular networks is that it needs to support intelligence network. In future VANETs, there will be a very large number of sensors installed and integrated in vehicles, and the edge cloud collects data and reprocesses it before sending them to other parts of the network, for example, conventional cloud servers.

Low latency and real-time application: low latency is the most fundamental challenge require in future VANETs regarding the needs of real-time applications. Future VANETs should support real-time applications, like safety and emergency messages , video streaming...etc with very low latency.

High bandwidth: in future, comfort applications such as high quality video streaming, augmented reality..etc will be in high demand. In addition, traffic applications for example 3D maps and navigation systems require frequent automatic updates.

Connectivity: The high communication requirements should be meet , future VANETs necessitate seamless connectivity between all connected vehicles in network. Connected and autonomous vehicles should maintain continuous and highly reliable communication between all nodes of network such as vehicles and fog devices. It should be able to avoid packet loss and transmission failures in the communication system.

1.9 Fog Computing:

A fog computing was first introduced and proposed by Cisco Systems, Inc., engineers it's a subclass of the cloud computing paradigm to the edge of wireless networks for IoT devices [2]. OpenFog Consortium drives the fog computing architecture. Its objective is to influence standard bodies to create standards so that the edge devices can inter-operate securely with other edge devices such as IoT and cloud services efficiently [44]. the implementation of IoT applications in the two-tiered architecture of the conventional cloud does not meet requirements related to mobility, low latency, and location awareness of smart devices. Thus, the evolution of the multi-tiered fog computing architecture is investigated. In general, users must download their data (multimedia flies, documents, etc.) from the cloud. In fog, the data will be stored in fog servers close to the users, decreasing latency and increasing throughput. In the first tier, ITS application is deployed in vehicles. the second tier is the fog platform, including fog devices such as RSUs and wireless access networks. the third tier is the hyper-scale data-center of the conventional cloud. Fog computing provides high bandwidth, low latency, location awareness, and Quality of Service (QoS) for streaming and real-time applications in vehicles [6]. Fog computing relies on resource virtualization by using hyper-visors for input/output resources and computing, virtual file systems for storage, and an SDN for network virtualization infrastructure [15]

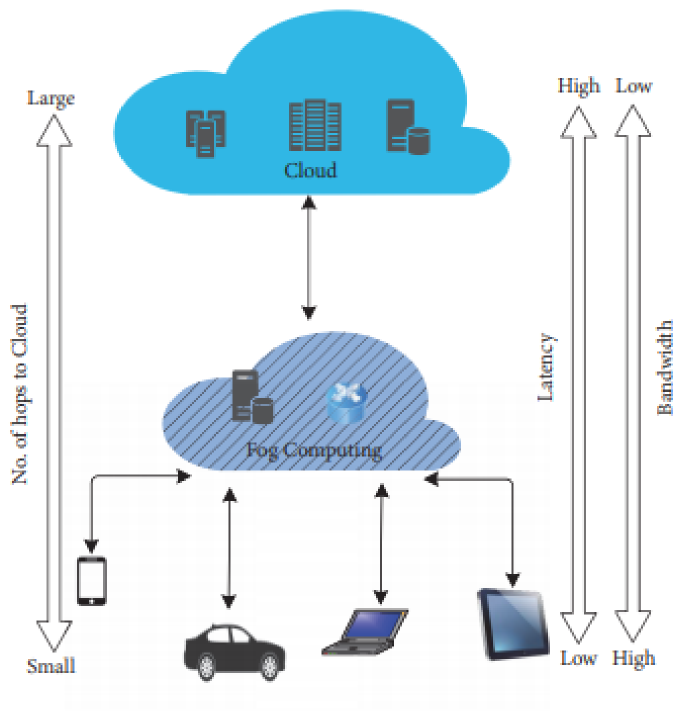


Figure 1.8: Comparison of number of hops, latency, and bandwidth from edge nodes to the cloud.

1.10 vehicular Fog Computing:

Vehicular fog computing extends the fog computing paradigm to conventional vehicular networks, communication and computation, storage services are provided at the edge of network . A fog server layer is deployed as intermediate layer between the vehicles and the cloud server. End users and vehicles are also considered part of the communication and computation,It targets applications with widely distributed deployments and requires a lot of resources and powerful communication and computation support, in this paradigm the vehicles play the role of infrastructure to meet the needs from both communication and computation which is an architecture that utilizes a collaborative multitude of end-user clients or near-user edge devices to carry out communication and computation.New applications, such as augmented reality (AR) techniques , self-driving,video streaming, etc., all deal with complex data processing and storing operations, which require higher level of data communication, computation, and storage. This poses great challenges to the existing conventional vehicular networks, particularly in terms of communication and computational capacities.[11]

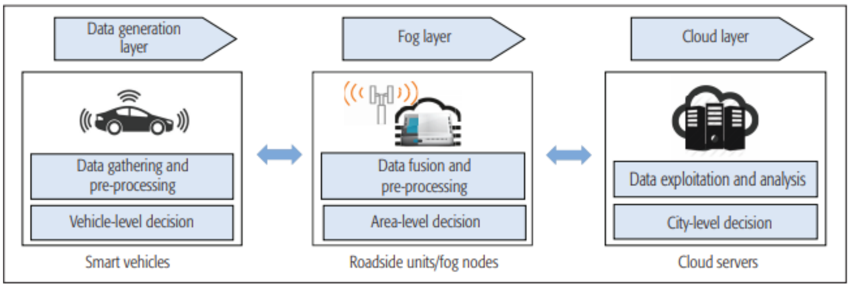


Figure 1.9: Architecture of vehicular fog computing

1.11 Conclusion

In this chapter, we present an introduction to the 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 dissemination of messages in a VANET network. Finally, the integration of CC and IT fog services in VANETs and the convergence of to Vehicular Fog Computing (VFC) paradigm.

In the next chapter. We will present the basic concepts of the video streaming such as: video evaluation metrics, video encoding techniques and video compression standards and video streaming over vehicular fog computing, related approaches.

Chapter 2

Video streaming over vehicular fog computing

2.1 introduction

Vehicular ad hoc networks plays the biggest role in the efficiency of road traffic and public safety and acting as a facilitator of services for passengers, drivers ..etc. Routing protocols are recently improved and used in vehicular networks have contributed to improvements in scalability, reliability, and the quality of the experience. Vehicles can cooperate and communicate with each other to stream videos of accidents and share visual information about events or disasters and provide visual information of the monitored area with great precision.

The definition of video streaming is: 'video streaming is a type of streaming media in which the data of video file is continuously delivered via network to a remote user without being downloaded on a host or device. It allows a video to be viewed online In this section we will present the basic concepts of the video streaming such as: video evaluation metrics, video encoding techniques and video compression standards.

2.2 VANETs and video streaming

2.2.1 VANET features

Due to the high speed and the mobility of vehicles leading to high dynamic of VANET topology, the fluctuation of vehicles density and environment obstacles are challenging for the video streaming, because they affect and rupture the communication path between the sender and the receiver when the video is transmitted. Consequently, these situations may produce network congestion and transmission errors, which decreases the video quality.[30][58]

2.2.2 Video streaming quality

video data have strict Quality of Service (QoS) and Quality of Experience (QoE) requirements like packet delivery ratio, transmission delay, Peak Signal to Noise Ratio (PSNR), Mean Opinion Score (MOS), and Structural Similarity Index Measure (SSIM). Two main issues that can deteriorate the video streaming quality in VANET are packet loss and also the transmission delay. so as to guarantee an honest video streaming quality, CISCO has defined some video streaming requirements just like the constraint of a transmission delay that not be more than 4 to five seconds and a packet loss rate that doesn't exceed % 5 [57]. a better PSNR and MOS values of video streaming are able to provide higher video streaming quality. the table shows PSNR and MOS requirement values for video streaming and also the mapping from PSNR to MOS. [42].

2.2.3 Video streaming metrics

The rating metrics of video streaming are classified into two main classes: objective rating and subjective rating. Objective assessment may be processed automatically using a set of knowledge like network technical parameters to gauge the video quality, while

Grade Scale	Image quality	Image impairment
5	Excellent	Imperceptible
4	Good	Perceptible, but not annoying
3	Fair	Slightly annoying
2	Poor	Annoying
1	Bad	Very annoying

Table 2.1: ITU-R quality and impairment scales

subjective assessment is predicated on human perception and knowledge to process this evaluation. In subjective evaluation, a variety of human observes are asked to observe and evaluate the video quality, the common of all human evaluations are given by Mean Opinion Score MOS [42]. International Telecommunication Union (ITU) defines within the recommendation ITU-R BT.500-11 five categories of the photographs quality and image impairment, which help the human to classify the perceived image. shows ITU-R image quality and impairment scales
[42]

The subjective assessment provides a most accurate evaluation because of the important human's perception than objective assessment, which is that the better criterion wont to evaluate the video quality. The limit of video streaming subjective assessment is that the high cost and time of manpower inviting to gauge the video quality, compared to objective assessment. We classify video streaming metrics in VANET into two essential classes: QoS and QoE.

2.2.4 QoS metrics of video streaming

Quality of Service (QoS) relies on the target assessment of video streaming, it's been defined [33] in two contexts: the user (customer) context and therefore the network provider context. In the user context, QoS is defined the attributes contributing essential within the use of service, whereas, in-network provider context, QoS is defined by parameters contributing to end-to end performance of service, where this end-to-end performance must reflect to user's requirements. Many works use QoS metrics to judge video streaming quality in VANET like Packets Loss Rate (PLR), PSNR, delay transmission, jitter and throughput, and others. We present in this subsection some QoS metrics used for video streaming evaluation in VANET, as summarized

Rate distortion of video frames

According to [27], the rate distortion Dd of video frames is calculated using the following equation:

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

Where De is the distortion caused by signal compression and Dv is the distortion caused by residual errors and inter-frame error propagation. The authors of [60] proposed a reconstruction of this rate distortion equation for the video streaming in VANET, where the video is transmitted through a multi-hop communication, by the following equation:

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

Where De is the distortion caused by signal compression at the encoder and Dn is the distortion caused by the network, Dn is calculated by the following equation:

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

Where Dparti is the distortion caused by the partition of network, Dexpir represents the distortion caused by the video deadline expiration and Derror is the distortion caused by the transmission error due to wireless fading channel and interference.

Start-up delay

In VANET, each vehicle has a buffer to stock the received packets, the process of video playback consists of two phases: charging phase and playback phase, when the buffer is empty the charging phase starts, it consists of charging the buffer by sufficient packets, when the buffer is charged by this packets (playback threshold) the playback phase is started. The time interval of charging phase is named start-up delay. According to [9] start-up delay (Ds) is given by the equation:

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

Where X(t) is the number of packets in the buffer at time t and b is the playback threshold. The average start-up delay is given by the equation:

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

Where λ is the arrival rate of the packets at the destination vehicle.

Frequency of streaming freezes

When the effective arrival rate of video streaming at the receiver vehicle λ is smaller than playback rate μ of this vehicle, the playback phase will probably stop, which produces the interruptions (streaming freezes) of video streaming at the application layer. According to [56] the average number of streaming freezes after t seconds (E(F)) is given by the equation:

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

Packet Delivery Ratio (PDR)

PDR represents the total number of received video packets over the total number of sent video packets. It is calculated as follows:

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

Average transmission delay

The transmission delay of a packet is the time interval between the sending moment of this packet at the sender and the complete reception time of this packet at the receiver level. The average transmission delay is the sum of all received packets delay divided by the number of the total number of the received packets. The average transmission delay is computed by the following formula:

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

Where, $RTimeOfPkt_i$ is the reception time of the $Packet_i$ and $STimeOfPkti_i$ is the sending time of the $Packet_i$

Decodable Frame Rate (DFR)

DFR is defined as the number of decodable video frames over the total number of sent video frames in a given EPER (Effective Packet Error Rate), it is calculated as follows:

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

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)

[26] defined the PSNR as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Mathematically, PSNR is defined via Mean Squared Error (MSE) [37], which measures the cumulative square error between original frame 'o' and distortion frame'd', as follows:

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

Where M.N is the frame size in pixel, o(m,n) and d(m,n) are the luminance pixels in position (m,n) in the frame. In mathematical way, PSNR is the logarithmic ratio between the maximum value of a signal and MSE.

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

QoS metric	Signification
Throughput	Effective number of transmitted data per unit time (bits/s)
Jitter	Difference between the delays of the i th and the (i+1) th data units. (delay variation)
Packet Loss Rate (PLR)	Percentage of lost packets at receiver vehicle compared to the sent packets from the source
Packet Delivery Ratio	Total number of received packets per total number of sent packets
Receiving Data Rate	Time from the start of downloading the first segment to the time that the playback begins
End to End Delay	Time interval between the start of packets sending by the source and the end the complete reception of this packets by the receiver
Overhead, Cost	Total number of transmissions
Start-up Delay	Time from the start of downloading the first segment to the time that the playback begins
PSNR	Ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation

Table 2.2: Some QoS metrics of video streaming in VANET

2.3 QoE metrics of video streaming

paragraph ITU defines in the recommendation ITU-T P.10/G.100 [35] the Quality of Experience (QoE) as the overall acceptability of an application or service, as perceived subjectively by endusers. QoE includes a subjective assessment of video streaming, which provides a more accurate evaluation compared to QoS based only on an objective assessment. We present in this subsection some QoE metrics used for video streaming evaluation in VANET.

QoE metric	Signification
Mean Opinion Score (MOS)	Average of all video quality subjective assessment
User Satisfaction Percentage (USP)	Percentage of time that MOS is over the user satisfactionthreshold
Mean Dissatisfaction Period (MDP)	Measurement of distribution of loss window

Table 2.3 continued from previous page

QoE metric	Signification
Structural Similarity Index Measure (SSIM)	Objective QoE metric measuring structural distortion of the video to obtain a better correlation with the user's subjectiveimpression

Table 2.3: Some QoE metrics of video streaming in VANET

2.4 Video encoding techniques

2.4.1 Scalable Video Coding (SVC)

SVC is based on the layered coding. The video stream is encoded into two types of layers; the former is a based layer, which represents I-frames and P-frames, where the latter is introduced as an enhancement layer representing the B-frames. The basic layer guarantees a based video quality and the enhancement layer increases the video quality [20].

2.4.2 Multiple Description Coding (MDC)

MDC [64] encodes the video streaming as a set of descriptions; each of them is a sequence of frames. When a frame of any description is perturbed, the decoder can recuperate this frame from other description, based on the redundancy recuperation mechanism of MDC.

2.4.3 XOR based coding

The XOR based coding is very widely used in error resiliency mechanisms such as Forword Error Correction (FEC) and Erasure Coding (EC), because this coding is efficient and not complicate. FEC and EC are based on the idea of adding redundant packets to original packets to successfully recover these later at the end receiver. When the XOR logical operation is applied on a set of packets (i.e. a, b,..., n) at the sender to produce one redundant packet, the presence of all these packets without one lost packet at the receiver allows the recovering of this lost packet.

2.4.4 Flexible Macroblock Ordering (FMO) coding

This encoding technique is based on the principal of dividing the frame into a set of slices; each slice consists of a set of Macro-Blocks (MBs). The Macro-Block is an elementary unit of slice. FMO is very powerful for the error resilience, for example if one slice is not available at the decoder, each lost macro-block of this slice may be surrounded by macro-blocks of other slices (above, bellow, right and left) [47]. Therefore, the lost macro-block can be recovered using the error concealment technique

2.4.5 Network Coding (NC)

NC is based on the idea that the intermediate nodes (re-encoder) mix the content of received units of data to produce new unit of data, which allows the reducing of the number of transmitted units of data, in order to increase the throughput of wireless network [54].There are many variations of NC like the Packet Level Network Coding (PLNC) in which the unit of data is the packet and the Symbol-Level Network Coding (SLNC) where the unit of data is a group of consecutive bits.

2.5 Related works

Vehicular ad hoc networks play the biggest role in the efficiency of road traffic and public safety and acting as a facilitator of services for passengers, drivers ..etc. Routing protocols are recently improved and used in vehicular networks have contributed to improvements in scalability, reliability, and the quality of the experience. Vehicles can cooperate and communicate with each other to stream videos of accidents and share visual information about events or disasters and provide visual information about the monitored area with great precision.

Fog computing presents a new architecture that "takes processing to the data" instead of "taking data to the processing" like cloud computing architecture. End users or edge devices are interconnected within a local fog network and collaboratively carry out storage, data processing, networking, and control tasks[28]

V2V communications emerged to inform context-alerts information, such as velocity, direction, emergency braking, for cars embedded with equipment to process this kind of data. and now, the technology involved. The cars equipped with own multiple cameras, sensors of multiple natures, such as sonar, light detection and ranging (LIDAR) sensors, and actuators for driving assistance and stability control. Moreover, public service authorities can perform better management of traffic conditions with more valuable information disseminated by the vehicles, assisting not only other common vehicles but ambulances, police, and fire trucks.

2.5.1 the CRPV Routing protocol

To successfully multimedia broadcasts over VANETs, reliable and powerful content delivery, scalability, and video-stream quality must be ensured and warranted. The CRPV proposes the following method:

(1) A calculation of collaborative gateway is performed to rank each vehicle in a linear list according to its gateway quality indicator,

(2)each vehicle have a routing table for in the V2V communication cluster is defined based on the GQI values,

(3) the collaboration of vehicles within the cluster is allotted to cut back the unnecessary exchange of video data during V2V communication. In most applications that include multimedia VANETs, all vehicles in an exceeding cluster don't must share the identical live video feed; in such a case, redundant information would likely be transmitted, thereby affecting network performance. Therefore, the CRPV is supposed to see the most effective nodes to broadcast video data in real-time when events are detected. The video data assist public safety agents; as an example, paramedics in ambulances can use these data to rearrange to supply care before they even reach the scene of an accident. to realize broad coverage in an exceedingly short time, the video data are broadcast to fixed end-users outside the VANET, like station or other vehicles that have access to a way better network interface at the time Examples include RSUs or LTE, as shown in Figure 2.[43]

The figure shows a VANET network, during which vehicles v1 and v9 have a Wi-Fi interface (V2V communications) and an LTE interface (V2I communications). Following an occurrence in lane 2, v1, which occupies lane 1, records the moment of the event (an accident) and shares the published video with its neighbors within its coverage area (v3 and v4). During receiving the video, v3 and v4 also share it. Vehicle v4 forwards the video to an RSU in its neighbor places, while v3 forwards it to a unique vehicle within the VANET, v6. given the communication capabilities of v1, v1 forwards the feed content to v9, which continues to be far from the event place and thus receives the video of the event before.[43]

CGs

All vehicles that are a part of a cluster represent CGs. The identification of vehicles that are eligible to be CGs starts when a cluster is made. At that point, one vehicle sends a beacon message over a particular (emergency) frequency to seek out vehicles that are available to determine a cluster after an accident on a highway. The vehicles that return the message at the identical frequency become part of the cluster formation. The frequency range is broken into 10-MHz channels. The messages follow the specifications for the wireless access in vehicular environment (WAVE) from the IEEE 1609 standard.Because security and authentication tools aren't used in the algorithm-development process

2.5.2 The CRPV algorithm

To classify CGs, an algorithm is formed to calculate the GQI of every vehicle in an exceedingly cluster. The algorithm employs several parameters, like the recording angles of the vehicles within the cluster, ratings of the region of interest in step with the events that have happened on the road, the speed of every vehicle within the cluster (to determine the time over which each vehicle will remain in an LTE cell), and therefore the location of every vehicle in the cluster per the eNB.

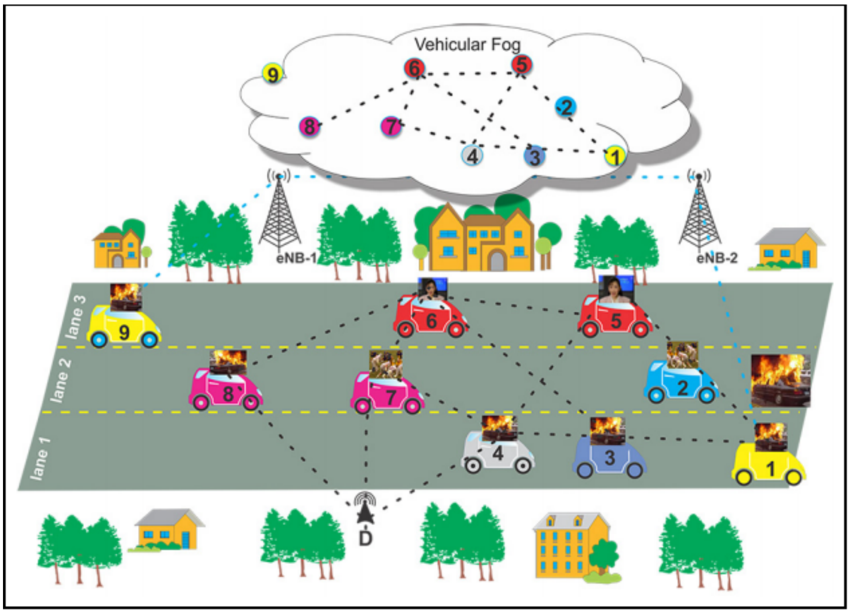


Figure 2.1: V2V and V2I communication with vehicular fog.

After the occurrence of a happening detected by the vehicle camera sensor, the algorithm of the CRPV begins its execution, identifying the amount of vehicles available for the formation of the cluster. During cluster formation, each vehicle should already be as its calculated GQI, since it'll be used for the formation of the routing table in each CG. A dynamic routing table is constructed from the data exchanged between each vehicle during cluster formation; among the knowledge is that the GQI that's dynamically used as a parameter within the routes to reflect changes within the conditions of the network. CRPV can solve complex routing cases faster and more efficiently. The cluster where there are several alternative routes to a destination functions because the cluster head, and they can still switch to an alternate route when the first route becomes unavailable and choose which route is an alternate to the destination. Finally, the transmission of video from the CG with the most effective GQI (cluster head) to a V2I network is performed. Figure below depicts the flow of the CRPV divided into three phases.

The first phase of the algorithm involve finding the number of vehicles to create the cluster. The second phase involves the calculation of the GQI to seek out the CGs. Finally, the third phase involves broadcasting the video from the CG with the simplest GQI to an LTE network or a V2I communication system.

2.5.3 Migration mechanisms Virtual Machine VM

The material resources of vehicles and road infrastructure are strictly limited in vehicle networks. The application technology in fog computing improve the use of intensive physical resources. In the new paradigm of fog-assisted vehiclar networks, vehicle mobility is a major challenge for the continuity of services in the cloud. Migration mechanisms Virtual Machine Dynamics (VM) address the problem. [62] A virtual machine allows a

Start

Determine the number of vehicles in the cluster formation For each vehicle;
Determine each vehicle recording angle;
Rate the speed of each vehicle in a linear list;
Rate the location of each vehicle according to the eNB;
Perform the GQI calculation;
Define a routing table for each vehicle;
Calculate the best CG to broadcast the video within the V2I network;

Finish

Table 2.4: Algorithm 1 logic used in the CRPV algorithm.

user to configure an environment and execute its unique processes without worrying about the physical resources involved.

resources are managed by hypervisors which, in turn, isolate virtual machines, althoughthat some can share the same physical resource, so each computer virtual (and its corresponding user) oblivious to its neighbors. The displacement of virtual machine from one physical location to another is simple and potentially transparent. These virtual machine migrations (VMM) can be triggered for manage hotspots or balance the load of resources. [50]

2.5.4 Real-time interactions between cloud and fog

Fog computing, extends the cloud computing paradigm to the sting of the network to decrease latency and network congestion, may be a relatively recent research trend Although both cloud and fog offering similar resources and services, fog is characterized by low latency with a wider spread and geographically distributed nodes to support mobility and real time interaction between cloud and fog nodes. Recent advances in wireless communication techniques have made it possible for vehicles to download and upload data from a roadside communications infrastructure via V2I communication, that is, by boosting collaboration between access technologies in a VANET-based scenario.[36]

2.5.5 Clustering and routing protocols algorithms over VANET

Numerous clustering and routing algorithms have been recently proposed for VANETs. There are differing types of cluster-based routing protocols accustomed attain efficient communication, but there are still many issues and challenges, like clustering with relation to bidirectional traffic modeling (for when traffic approaching the roadside units (RSUs) from both directions is unspecified), data dissemination techniques, routing, QoS guarantee, and security.[52]

Latif and al.[29]reviewed several studies and compared numerous existing multi-hop data broadcast protocols in terms of assorted attributes like data-forwarding strategies, objectives, architecture types, application scenarios, assumptions, evaluation metrics, and simulation platforms. Furthermore, a resourceful taxonomy of those protocols was introduced supported the road scenarios with critical discussions of every categorization with relevance strengths, weaknesses, and important constraints. Finally, the assorted perspectives, challenges, and shortcomings of the prevailing studies were discussed.

Bagherlou and Ghaffari[19] proposed a cluster-based reliable routing algorithm for VANETs and reliable applications. In this way, simulated annealing was used for the appropriate clustering of nodes, and the parameters of node degree, coverage, and ability were considered in the proposed method.

2.5.6 cluster-based routing

Qureshi and al.[48] proposed the cluster-based routing protocol for sparse and dense networks to handle dynamic typologies and high mobility of car nodes. The protocol is accountable for putting in a route between source and destination nodes. However, because of the high mobility of vehicles and therefore the intermittent nature of wireless channels, the amount of information downloaded by individual vehicles in V2I communications is incredibly limited. This limitation severely restricts the quality of multimedia applications; consequently, routing protocols adapted to the characteristics of VANETs must be developed by considering that the fog computing paradigm are the longer term of computing technology.

2.5.7 The passive clustering-aided routing (PassCAR) protocol

The passive clustering-aided routing (PassCAR) protocol for use in VANETs[55] is a cluster-based routing protocol that aims to identify candidates for incorporation in cluster structures with stable (same direction) and reliable characteristics during the route discovery process to improve routing performance in one-way and multiple-lane highway scenarios. As specific goals of the proposal, each eligible vehicle determines its own priority in the cluster using metrics such as node degree, expected streaming, and link lifetime. The results obtained by the authors are compared with those of the passive cluster mechanism proposed by Hashim and al.[22] for use in VANETs

According to the authors, the PassCAR protocol increases the probability of successful route discovery and selects the foremost appropriate nodes for participation within the created cluster. This well-defined structure significantly improves the packet delivery rate and achieves increased throughput in networks because of its preference for reliable, stable, and lasting routing paths. Routing metrics also analyze the probability of forwarding route request (RREQ) packets per hop when selecting the following routing node to create an efficient cluster structure that promotes reliable and lasting routing. This protocol presents problems that balance scalability and reliability, because it considers only vehicles going in the identical direction that have stable characteristics. The system becomes compromised when one among the vehicles changes its characteristics. The forwarder smart selection protocol for the limitation of the printed storm problem (i.e. the selective reliable broadcast (SRB) protocol)[3] may be a cluster-based routing protocol whose purpose is to limit the amount of packets streamed over an opportunistic choice of vehicles. The packets are retransmitted only by the chosen vehicles to scale back the amount of routers, thus preserving an appropriate level of QoS.

2.5.8 The SRB protocol

The SRB protocol uses the behavior of vehicles in an vehicular ad hoc network partition to automatically detect clusters using zones of interest. Packets are routed only to opportunistically selected vehicles, which are chosen as CHs. The authors assessed the SRB protocol in several vehicle scenarios that mainly represent realistic environments, like urban areas and highways. The limitations posed by the streaming congestion problem within the SRB format manifests as a decrease in the number of next-hop forwarders. The authors also compared the efficacy of the SRB protocol with traditional protocols and a content-based dissemination approach due to its ability to see sets of vehicles with common characteristics. The SRB protocol prevents the re-streaming of messages (which may be a limitation imposed by the published problem) and detects clusters automatically and quickly. The proposed approach considers the method of message re-streaming within a VANET by selecting a limited number of vehicles as potential next-hop forwarders. The SRB protocol isn't a typical broadcast routing protocol; instead, it detects sets of vehicles in a very quick and efficient way and chooses a CH for every detected cluster. The CH is then chosen because the next message forwarder. The SRB protocol breaks the region occupied by the vehicles into adjacent sectors; moreover, the vehicles are all equipped with global positioning system (GPS) units and capable of estimating their own positions. Each partition freely transmits messages from the originating vehicle and is identified as a part of a circle. the scale of every sector varies dynamically in step with the printed direction of each vehicle. This protocol poses problems that balance scalability and reliability, considering that it's packet re-streaming limitations and limits the amount of vehicles that are allowed to transmit. These characteristics compromise the system when the scenario includes few vehicles.[3]

2.5.9 Video croudsourcing for vehicular fog computing

Chao Zhu and al[10],Applying vehicular fog computing technology for real-time analytic of crowdsourced dash camera video by examining the challenges and feasibility. rather than forwarding all the video to the cloud, they propose how to show commercial fleets into vehicular fog nodes and to utilize these nodes to collect and process the video from the vehicles within communication ranges.

Table 2.5: focused areas of routing data in VANET and fog computing conducted by existing surveys

Focused topic of VANET And Vehicular Fog computing	**Description**
the CRPV Routing protocol :	To successfully deliver multimedia broadcasts over VANETs, reliable content delivery, scalability, and video-stream quality must be ensured using fog computing
Migration mechanisms Virtual Machine VM	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	Recent developement in wireless communication techniques have made it possible for vehicles to download and upload data from a roadside communications infrastructure via V2I communication that is, by boosting collaboration between access technologies includes cloud computing and fog computing [36]

Table 2.5 continued from previous page

Focused topic of VANET And Vehicular Fog computing	**Description**
Clustering and routing protocols algorithms over VANET	Such as clustering with respect to bidirectional traffic modeling (for when traffic approaching the roadside units (RSUs) from both directions is unspecified), data dissemination techniques, routing, QoS guarantee , and security [52] compared numerous existing multi-hop data broadcast protocols in terms of various attributes such as data-forwarding strategies , objectives,architecture types , application scenarios,assumptions , evaluation metrics, and simulation platforms
cluster-based routing	To handle dynamic typologies and high mobility of vehicle nodes. The protocol is responsible for setting up a route between source and destination nodes [48]
The passive clustering-aided routing (PassCAR) protocol	Aims to identify candidates for incorporation in cluster structures with stable (same direction) and reliable characteristics during the route discovery[55]
The SRB protocol	Protocol uses the behavior of vehicles in anad hoc network partition to automatically detect vehicle clusters using zones of interest. Packets are routed only to opportunistically selected vehicles, which are chosen as CHs [3]

Table 2.5 continued from previous page

Focused topic of VANET And Vehicular Fog computing	**Description**
Video croudsourcing for vehicular fog computing	discuss the challenges of integrate vehicular fog computing for real- time analytics of crowdsourced dash camera video between all nodes and stream any video event [10]

2.6 Conclusion

In this chapter we presented the principle of video streaming in VANETs, which is based on video streaming metrics and encoding techniques ,quality of service (QoS), quality of experience (QoE), then in next section , we presented The works cited in this approach that deal with the problem of data scheduling for vehicular fog computing focusing on video streaming application, routing protocols..etc.

In the next chapter we will mention the proposed approach for video streaming data dissemination. After that, we will show how vehicle fog nodes or virtual clusters play the role of gateway and collaborate in the process of communication and computation, then we will present the meta-project model, the organization chart, the architecture of the model. At the end of the chapter, we will present model the algorithms.

Chapter 3

Vehicular Fog Nodes For Traffic Video Streaming

3.1 Introduction

In the previous chapter, we presented a state of the art concerning the dissemination of video streaming information 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). We attempt to show the important role of Vehicular Fog Computing applications, video streaming in particular, to increase the road efficiency by improving traffic safety and by acting as a service facilitator for passengers, drivers and public safety officers. Recent improvements in routing protocols and typologies for video streaming have helped improve the scalability, reliability, and quality of the information sharing experience. Vehicles can cooperate with each other to broadcast videos of accidents or disasters and provide visual information about the area being monitored with great precision.

In this chapter, we will propose data scheduling strategy for the application of video streaming in a vehicle fog network by integrating an approach of clustering . In particular, we proposed an algorithm which 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.

3.1.1 Objective

the purpose is to show the viability of fog computing in the area of video streaming in vehicles.With the rise of autonomous vehicles. The cloud fails to address these options due to latency problems experienced during high internet traffic.To improve video streaming speeds, fog computing seems to be the best option.

Fog computing brings the cloud closer to the user through the use of intermediary devices known as fog nodes. It does not attempt to replace the cloud but improve the cloud by allowing faster upload and download of information. This chapter explores two algorithms that would work well with vehicles and video streaming. This is simulated using a omnet++ application scenario, and then graphically represented.

3.1.2 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.

Traffic events pose a major problem for public safety officers during the time that elapses between event occurrence . aid The vehicular ad hoc networks (VANETs) emerged to deal with this events by signaling emergency situations, such as hard braking, mobility intentions, and collisions. However, context messages does not show details about the event in order to engage proper tools for the emergency teams. Vehicles equipped with camera can stream video content to the public service authorities to reduce rescue time.However, these video streams require quality of experience (QoE) to deliver minimum quality level on the user experience and provide a clear view of the content.

Vehicular applications With the emergence of ever-growing, the challenges to meet the needs from both communication and computation are increase . Without powerful communication and computational support, several vehicular applications and services will remain in the concept phase and cannot be put into practice in daily life.

Therefore, we consider utilizing vehicles as an infrastructure for communication and computation called vehicular fog computing (VFC), which is an architecture that utilizes a collaborative multitude of end-user clients or near-user edge devices to establish communication and perform computation based on the utilization of the individual communication and computational resources of each vehicle. Considering the technical advances and economic advantages of integrated architectures and cloud computing, we conjecture that the realization of a real-time cloud, called a fog, which 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.

V2V communications previously emerged to inform context-aware informations, such as velocity, direction, and emergency braking, for cars embedded with equipment to process this kind of information. The technology evolved, and now, the cars own multiple cameras, sensors of multiple natures, such as sonar, light detection and ranging (LIDAR) sensors, and actuators for driving assistance and stability control. All data generated by these sensors can enhance the overall car mobility by maintaining real-time maps of street conditions. Moreover, public service authorities can perform better management of traffic conditions with more valuable information disseminated by the vehicles, assisting not only others common vehicles but ambulances, police, and fire trucks.

3.1.3 Our model

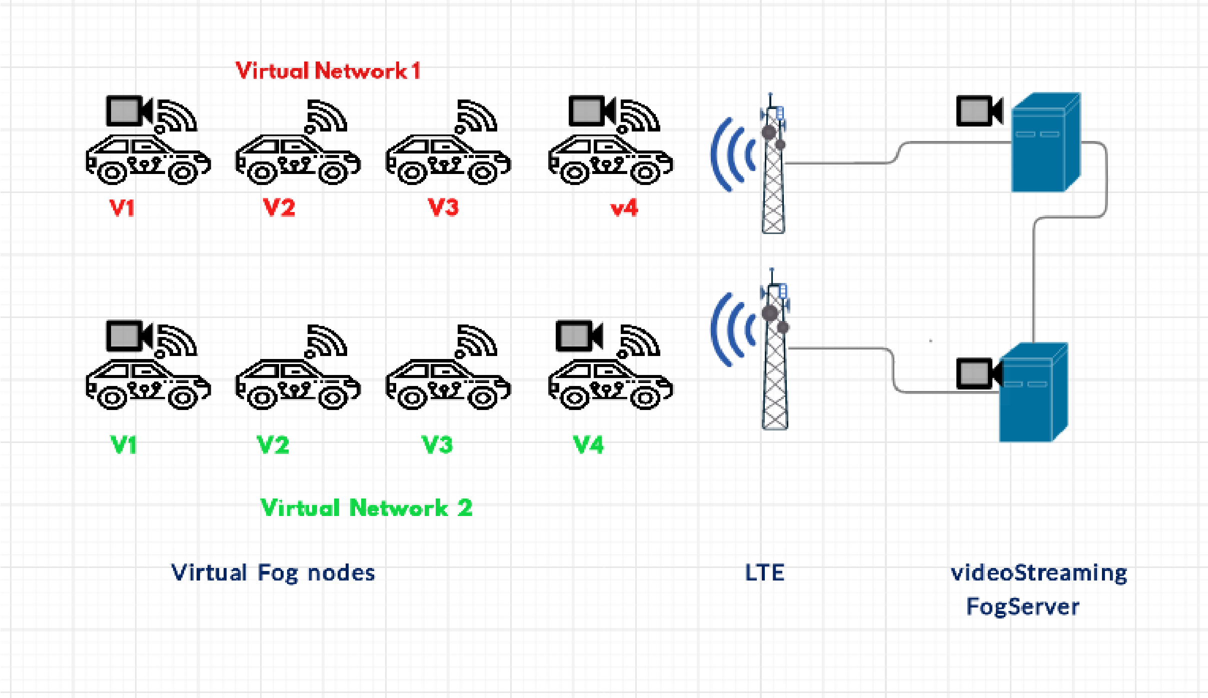


Figure 3.1: Video Streaming in vehicular fog computing architecture

this figure shows a sample VANET, all vehicles have both an LTE interface (V2I communications) and a Wi-Fi interface (V2V communications).vehicle records the moment of the event (an explosion) and shares the broadcast video with neighbor vehicles within its coverage area. Upon receiving the video, v3 and v4 also share it. Vehicle v4 forwards the video to an LTE access point in its vicinity, while RSU forwards it to Fog Server, Moreover, given the communication capabilities of v1, which also has an LTE interface, v1 in virtual network 1 forwards the feed to v1 in virtual network 2, which is still far from the event site and thus receives the video of the event in advance.

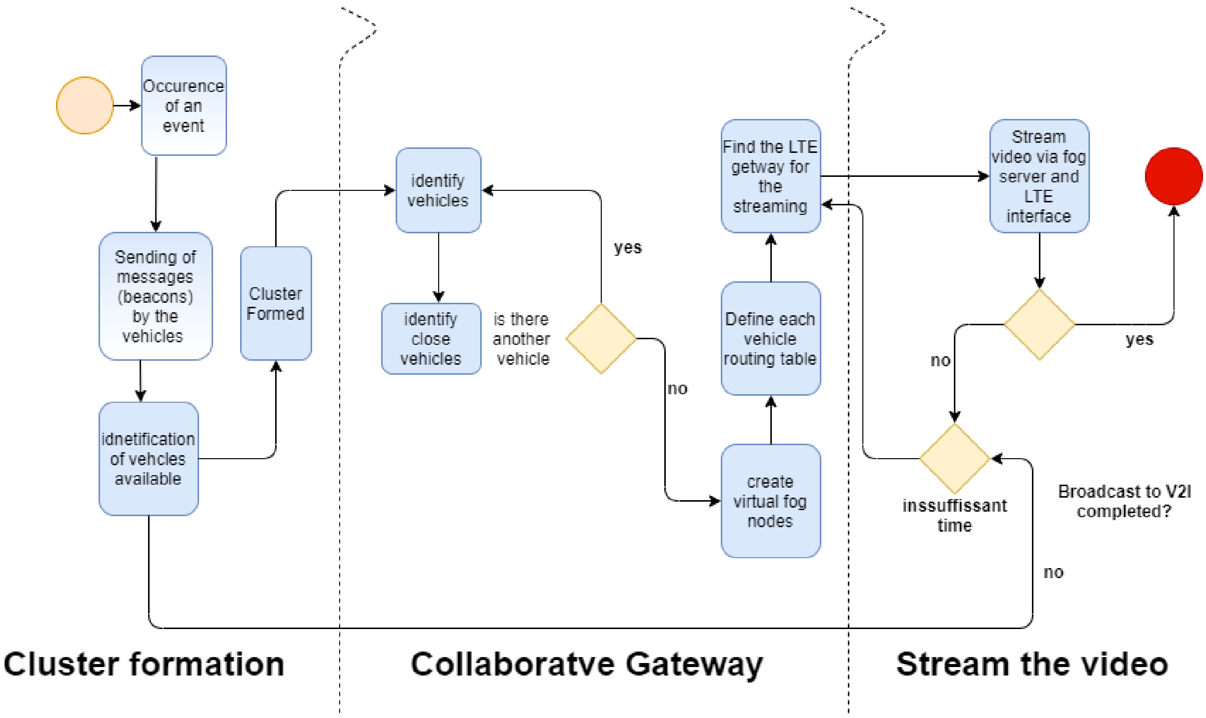


Figure 3.2: Flowchart of our model

To successfully deliver video broadcasts over VANETs, reliable content delivery, scalability, and video-stream quality must be ensured. The Proposed architecture: we have the routing table for each vehicle in the V2V communication cluster is defined based on the joint collaboration of vehicles in the cluster is carried out to reduce the unnecessary exchange of data during V2V communication. In most applications that employ multimedia VANETs, all vehicles in a cluster do not need to share the same live video feed; in such a case, redundant information would likely be transmitted, thereby affecting network performance. Therefore, this solution is designed to choose the best virtual fog nodes to distribute video data in real time when events are detected. The video data assist public safety agents; for example, paramedics in ambulances can use these data to prepare to provide care before they even reach the scene of an accident, the video data are streamed to fixed users outside the VANET, such as police headquarters or other vehicles that have access to a better network interface at the time. Examples include RSUs or LTE,

After the occurrence of an event detected by the vehicle camera sensor, identifying the number of vehicles available for the clustering. During cluster formation, each vehicle should already be as its calculated , since it will be used for the formation of the routing table in each vehicle. A dynamic routing table is constructed from the information exchanged between each vehicle during cluster formation.dominant set can solve complex routing situations faster and more efficiently. The cluster where there are several alternative routes to a destination functions as the cluster head, and they can still switch to an alternate route when the primary route becomes unavailable and decide which route is an alternate to the destination. Finally, the transmission of video from the vehicle to a V2I network is performed .we can divide this operation into 3 phases: The first phase involves finding the number of vehicles to form the cluster b. The second phase involves the calculation and creation of virtual fog nodes. Finally, the third phase involves broadcasting the video from the vehicles to an LTE network or a fog server V2I communication system.

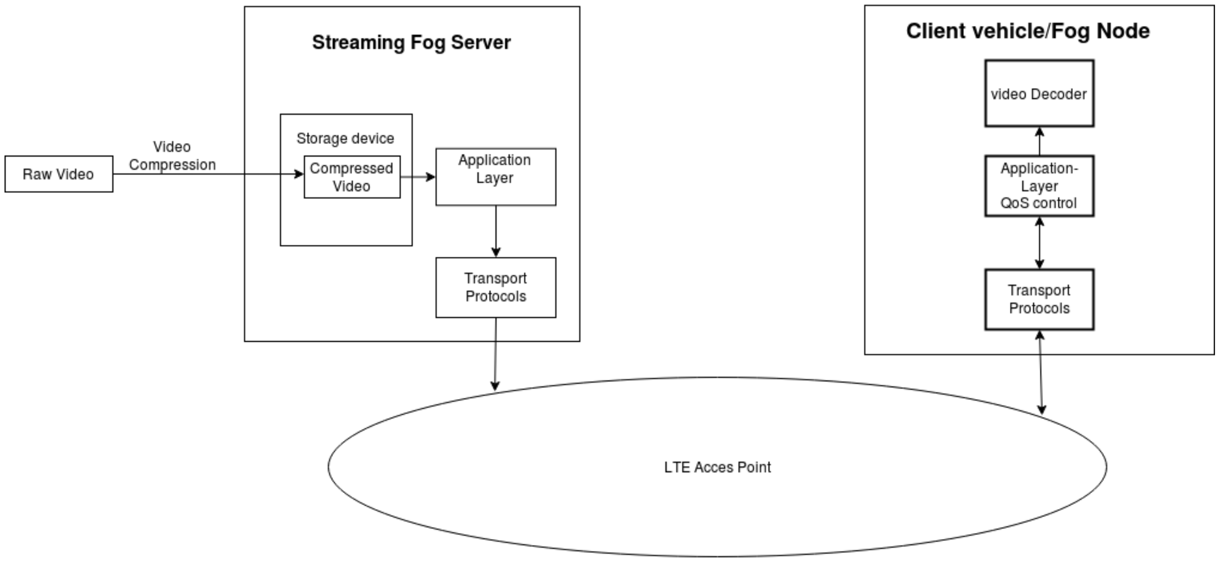


Figure 3.3: Architecture for Video Streaming for our model

3.2 Scenario

The dissemination of traffic information specially video streaming in a VANET network is a major issue, several project and studies are done in this subject, researchers have proposed to utilize the video data collected from vehicles for parking space detection, traffic monitoring, and assisted driving...etc. For many applications that require real-time analytic of high-resolution video streams, moving data to the cloud for processing is not feasible due to the high latency caused by the round-trip between vehicles and the cloud. Meanwhile, few vehicles today have sufficient computing power to conduct complex video analytic locally.

Different architectures of vehicular fog computing (VFC) that include vehicular cloudlets (i.e., cloudlets carried by vehicles) have been proposed in the literature. proposed to turn vehicles, especially slow-moving and parked vehicles, into cloudlets, and to form a local cloud called JamCloud by gathering the computing resources available on nearby vehicles.proposed to turn every vehicle (e.g., autonomous cars) into a cloudlet or virtual networks that has substantial processing capability and storage for processing local sensor data, and to share 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 term 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 point and RSUs, serve the vehicles within range for single-hop communication and multi-hop communication. Additionally, due to the mobility of vehicles , the service from vehicular fog nodes can be dynamically managed and dispatched on demand, and the over-subscription of resources can be reduced.

this model is working as follow.First LTE access point and vehicles exchange messages of type(beacon,ProbResp, wlan-ack,auth) in the procedure of beaconing and authentication ,second the vehicles send to LTE acess point Association request (Assoc) in this situation the LTE respond with OK (AssocResp-OK) ,Third The vehicle who needs to stream video send to close vehicles and LTE access-point a message of type video stream request(VideoStrmReq) then it forward it to fog server after that send video streaming packets to LTE and broadcast video data to all vehicles using udp client/server application .

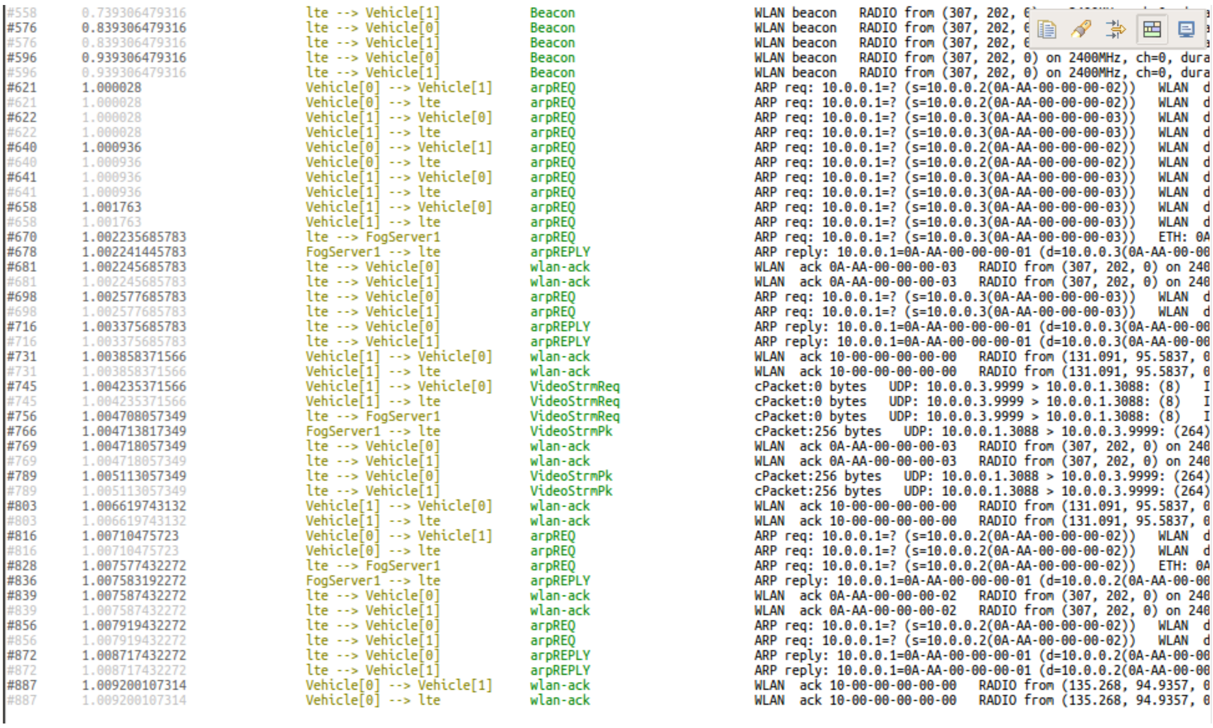


Figure 3.4: Event messages

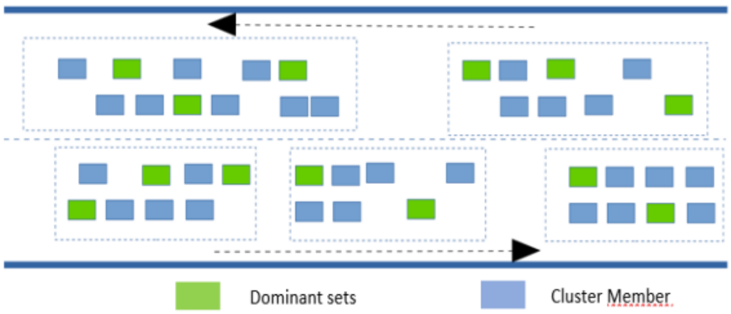


Figure 3.5: Cluster architecture

3.3 Dominant set algorithm

in this chapter we try to use, the cluster technique in order to predict the groups of vehicles share the same video traffic or that 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.).

Algorithm 1 Dominant set

Input:
  int i,j
  vis[100000] bool
  graph table[table[int]]
Output: S
  table(int)**solve_dominant**(int fog_node,int edge)
  Begin
  table(int) S;
  for *i=0 i++ i<= fog_node* **do**
    if
    vis[i]=false **then**
      S=S+i
      vis[i]=true
      for
      j=0 j++j=lenghth.graph[i] **do**
        if
        vis[graph[i][j]=false **then**
          vis[graph[[i][j]]=true
        j=j+1
    i=i+1
  return S

3.4 Intermittent Sets algorithm

subsectionIntegration of the Cluster into Vehicular fog network

In VANETs, vehicles close to each other form a cluster or access point, each cluster has a Cluster Head, in our case, we use cluster heads and fog servers for the computing operations, and instead of having a single head cluster, we choose several members from the cluster to make calculations, the choice of these members is made by the dominant group algorithm (Dominating Sets Algorithm), Since VANET networks are known for their very dynamic mobility, the formation of clusters is an effective solution to maintain the links between vehicles. But at the same time, it will be difficult to keep the shape of the cluster because of the high speed of the nodes, so the application responsible for creating the cluster must be an adaptive application and hold account that the node that leaves a group must enter another if it meets the conditions.

Algorithm 2 intermittent set algorithm

```
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]]
bool exist=false
ListNet=arcs
while ListNet.lenghth<>0 do
    com=0
    subNet [container[int,int]
    NbNetworks++
    for itr=ListNet.First itr++ itr>=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++ it>=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)
    itr++
for itr2=subNet.First itr++ itr>=subNet.end do
    NetVec.add(subNet)
return NetVec
```

3.5 Conclusion

In this chapter, we have proposed a data scheduling strategy for the application of video streaming in a vehicle fog environment. In particular, we proposed an algorithm which 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.

In the next chapter we ill present our final project, the implementation of the various algorithms and functions and the implementation of the module Cluster Control and video streaming application using omnet++.Then, we describe the scenario results, at the end, we will extract the simulation statistics.

Chapter 4

Implementation And Simulation

4.1 Introduction

the previous chapter was devoted to the proposed approach by presenting their characteristics, these 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 the video streaming. Then we will discuss The obtained results.

4.2 Simulation Environments

4.2.1 The OMNET ++ Simulator

OMNeT ++ is a C ++ simulation library and infrastructure based on components, expandable and modular, which also include integrated development and graphical execution environment. Domain-specific features (support communication networks, queuing networks, performance evaluation, etc.) are provided by model frameworks developed as as independent projects. There are extensions for real-time simulation, emulation networking, support for alternative programming languages (Java, C), integration database and several other functions.[59]

4.2.2 The conception of OMNeT ++

OMNeT ++ was mainly designed to support network simulation with large scale. This objective leads to the following main design requirements:

Activate large-scale simulation. Simulation models must be prioritized and constructed as much as possible from reusable components.

The simulation software should facilitate viewing and debugging of the simulation in order to reduce the debugging time which generally occupies a large part of the simulation projects.

The simulation software must be modular, customized and allow integration simulations in larger applications such as planning software network.

Data interfaces must be open. It should be possible to generate and process input and output files with commonly available software tools.

Provide an integrated development environment that greatly facilitates development of the model and analysis of the results. [16]

4.2.3 Simulation platforms

INET

INET Framework is a library of open source models for the environment OMNET ++ simulation. It provides protocols, agents and other models to researchers and students working with communication networks. INET is particularly useful when designing and validating new protocols, or when exploring new or exotic scenarios. The INET platform provides several functions for VANETs projects specially, among these advantages:

The positioning and the mobility of the nodes are important in the scenarios of simulation of VANETs. In INET, mobility is added to nodes in the form 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 obtain movements more complex.

The variety of routing protocols for MANETs in general, the protocols routing can be classified as reactive or proactive. INET contains various routing protocols for VANETs of the two categories, among the protocols of reactive (AODV) and proactive (DSDV) routing.

In inter-vehicle simulations, terrain has profound effects on propagation of the signal. For example, vehicles on either side of a mountain cannot not communicate directly with each other. For this, the INET platform describes a ground model to describe the 3D surface of the terrain. Several platforms are developed in OMNET ++, for example CASTALIA, also can simulate networks without mobile queues, but only the integrated peripherals of low power, for example wireless sensor networks (WSN), for this, INET is the platform used in VANETs simulation scenarios. [24]

ICanCloud

ICanCloud is a simulation platform designed to model and simulate cloud computing systems, which is aimed at users who deal closely with this type of systems. The main objective of this platform is to anticipate the trade-offs between cost and performance of a set of applications running in specific hardware, and then provide users with useful information about these costs. However, it can be used by a large number of users, from basic active users to developers large distributed applications. Among these advantages, one of the principles of these design as the possibility of carrying out great experiences. This is why iCanCloud supports C ++ language. Thanks to that, iCanCloud can use all the memory available on the machines running the experiments, for 32 and 64 bit machines, because another CloudSim simulator for example cannot manage more than 2 GB of memory in 32-bit systems due to the fact that it is written in Java. A extension of the NS2 network simulator, GreenCloud focuses on the simulation of communications between processes running in a packet-level cloud. Of the same way as NS2, GreenCloud is written in C ++ and OTcl, which is a drawback, you must use two different languages to implement a single experiment, on the other hand ICanCloud is written only with C ++. Among the problems of cloud computing is the energy consumption of data, even iCanCloud, it doesn't provide power consumption patterns, although this to be included in future work. None of the existing cloud simulation tools (CloudSim, MDCSim and GreenCloud) has a full graphical interface, however, iCanCloud has an interface simple graphics that allow users to easily create experiences. The main drawback of the existing platforms (CloudSim, MDCSim and GreenCloud) is a design principle in ICanCloud, existing simulation tools do not can simulate that an experiment on only one machine at a time, on the other hand, ICanCloud can simulate an experiment on a group of machines.[12]

4.3 The simulation

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

4.3.1 Communication architecture

the communication architecture our scenarios 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 architectures predefined by the WAVE standard. The communication architecture we propose follows the layered architecture of the WAVE model and the OSI (Open System Interconnection) model. However, this architecture integrates several protocols, namely the Internet protocol (IPv4), ARP, ICMP, etc..

4.3.2 Vehicular fog project for video streaming

Start the OMNeT **++** IDE by typing omnet **++** in your terminal. Once in the IDE,

choose: New **− >** OMNeT **++** Project from the menu.

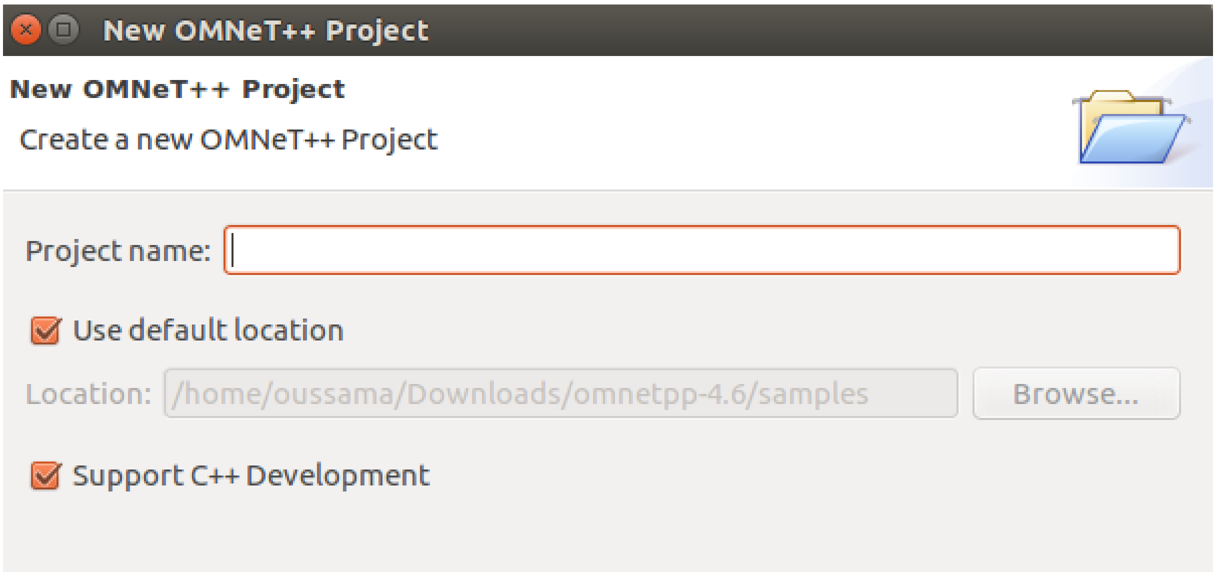


Figure 4.1: starting the project

4.3.3 Vehicular fog environment for video streaming

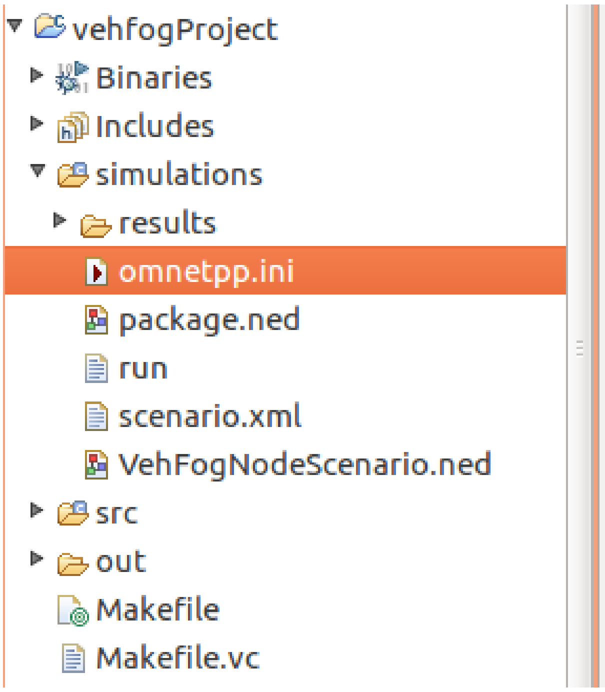


Figure 4.2: Folder of simulation

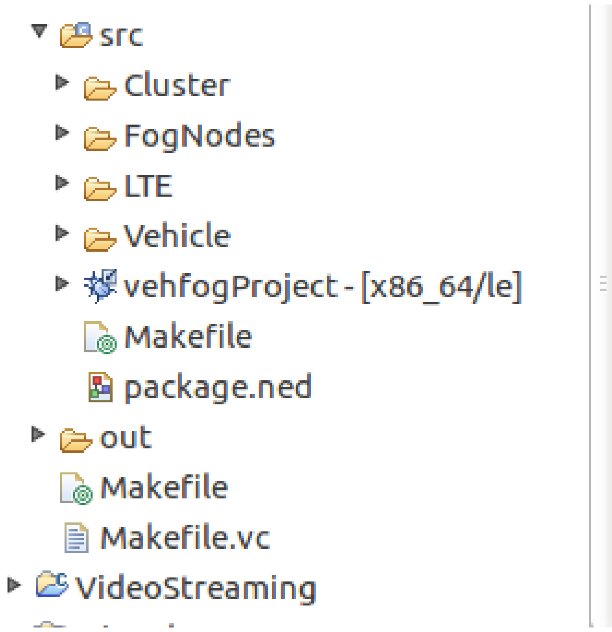


Figure 4.3: Folder src

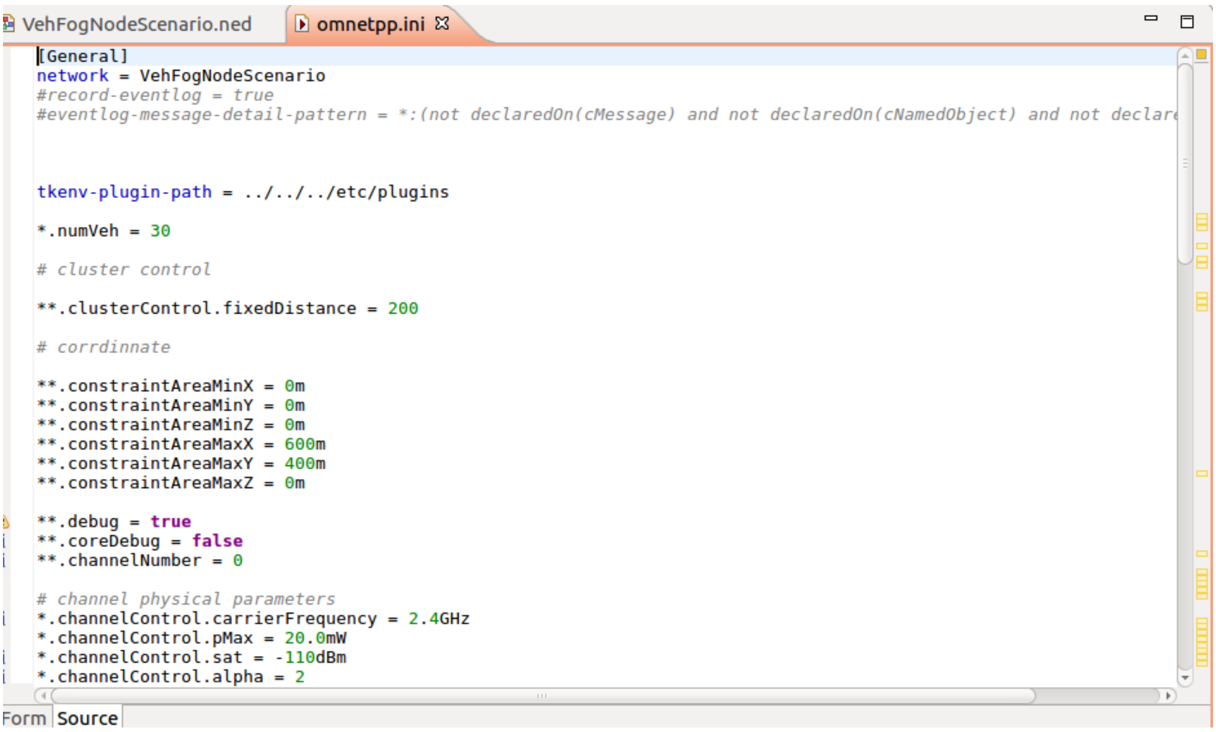


Figure 4.4: omnetpp.ini file

Our project contains two essential containers 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 4.2), the configuration is concerning must be the values after a predefined execution time,The src folder includes taking three files

; Cluster and FogNode , LTE and see (figure 4.3), 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.

4.3.4 Build and run simulations

An OMNeT ++ model consists of the following parts:

Description of the NED topology(.ned files) describing the structure of the module with parameters, doors, etc. NED files can be written using any editor text editor, but OMNeT ++ IDE provides excellent support for graphical editing and bidirectional text editing.

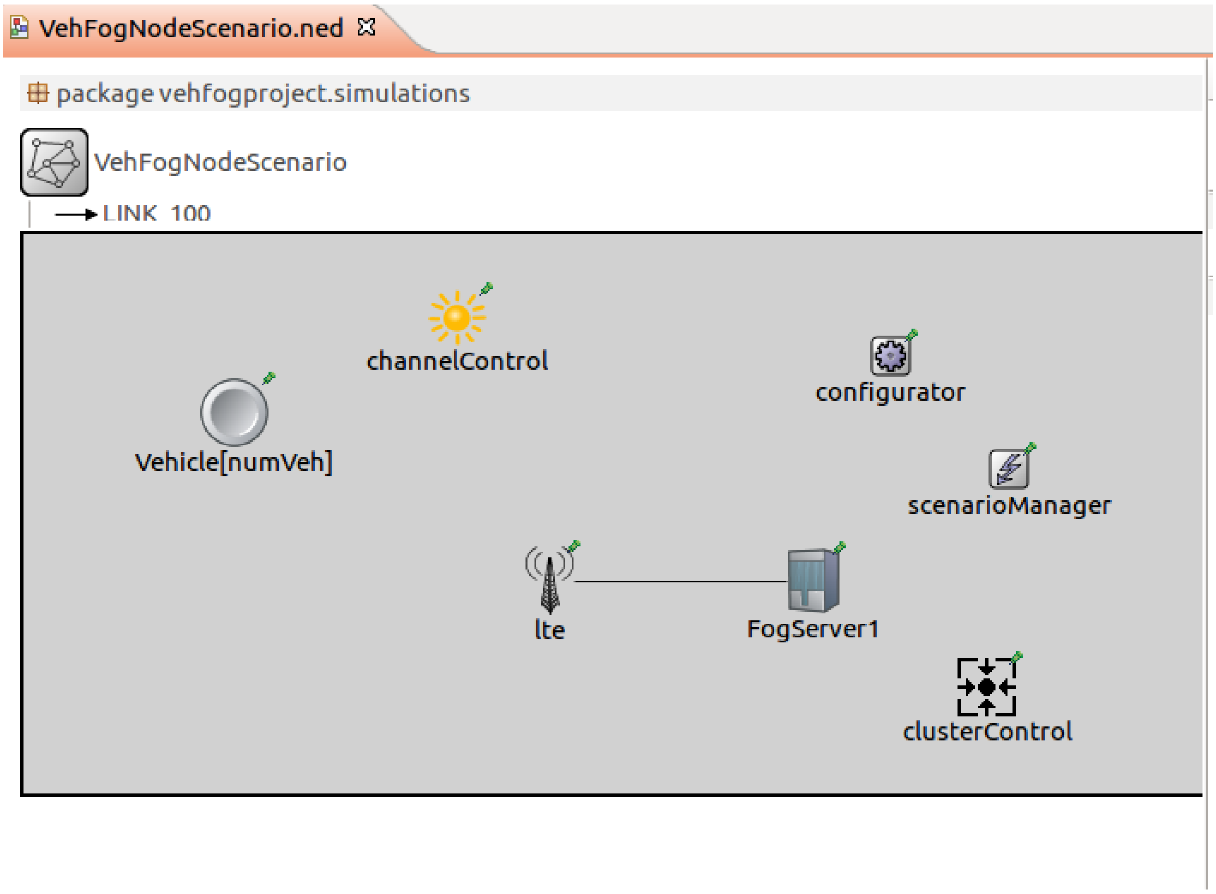
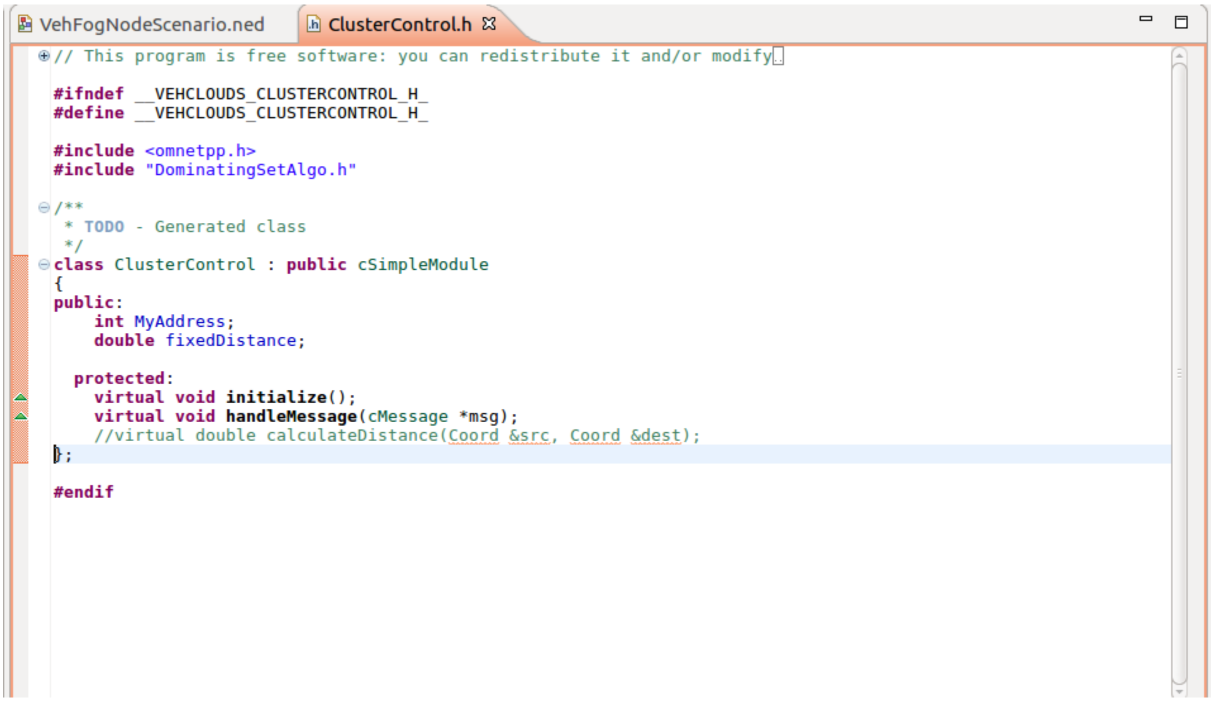


Figure 4.5: File.NED




```
// 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 4.6: File ClusterControl.h

Message definitions (.msg files) used to define message types and to add data fields to it. OMNeT ++ will translate message definitions into full C ++ classes.

Simple module sources These are C ++ files, with the suffix .h / .cc.

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

User interfaces OMNeT ++ user interfaces are used in running the simulation to facilitate debugging, demonstration, or execution by lots of simulations. They are written in C ++.

Omnetpp.ini To be able to run the simulation, an omnetpp.ini file must be created. omnetpp.ini contains parameters that control the execution of the simulation, values for model parameters.

4.4 The implementation

4.4.1 Dominant Sets Algorithm

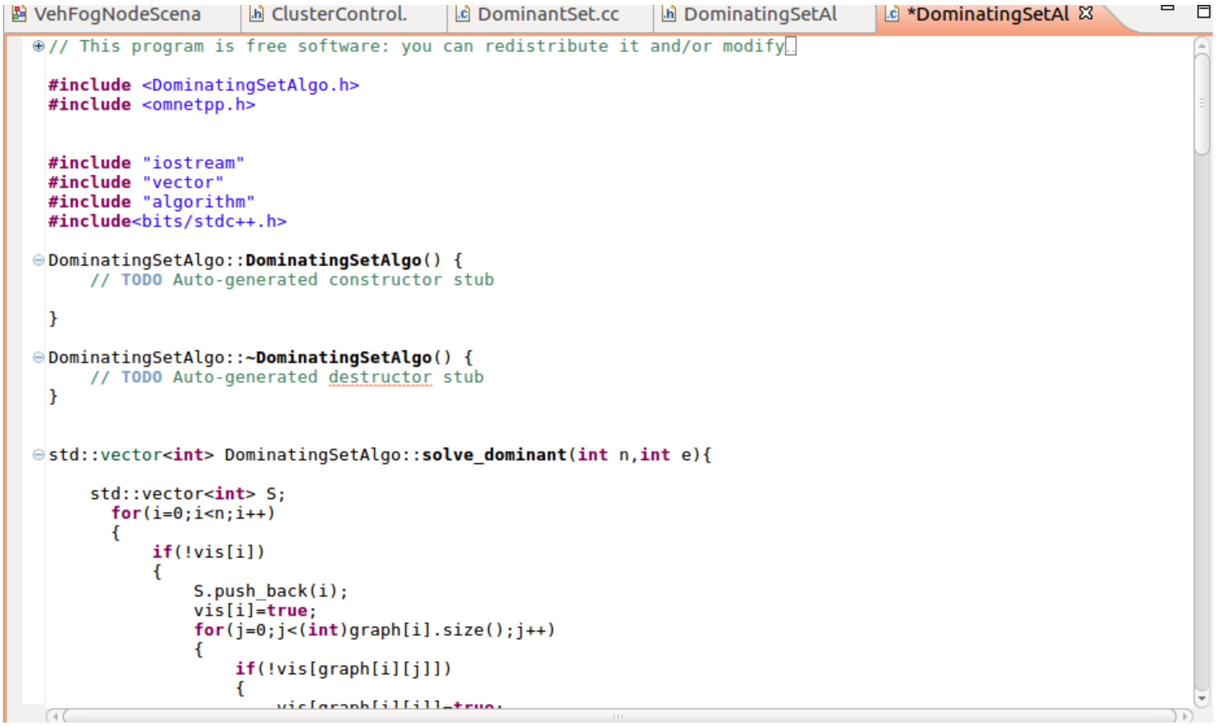
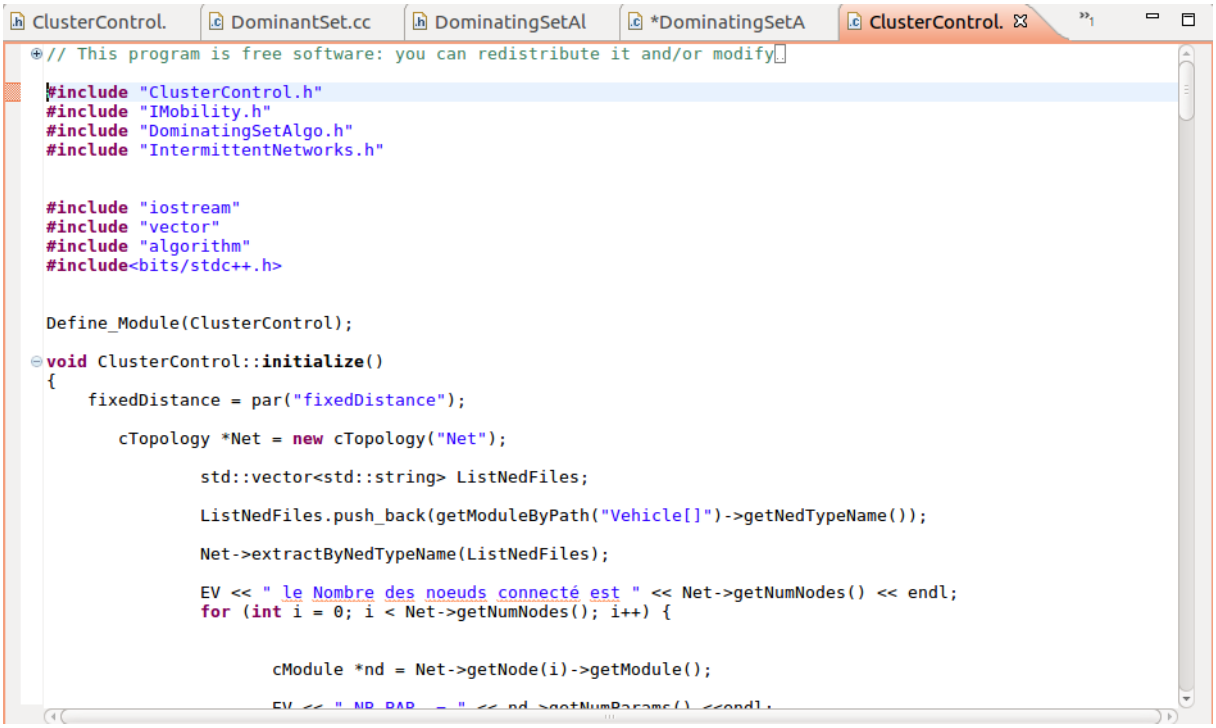


Figure 4.7: dominant set

4.4.2 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();
```

Figure 4.8: Cluster control

4.5 Nodes of simulation

After opening OMNET ++, You can build a simulation by using the OMNET palette, the OMNET palette contains the various modules of the ICanCloud platform and INET and the other referenced platforms (MiXiM, Castalia, etc...)

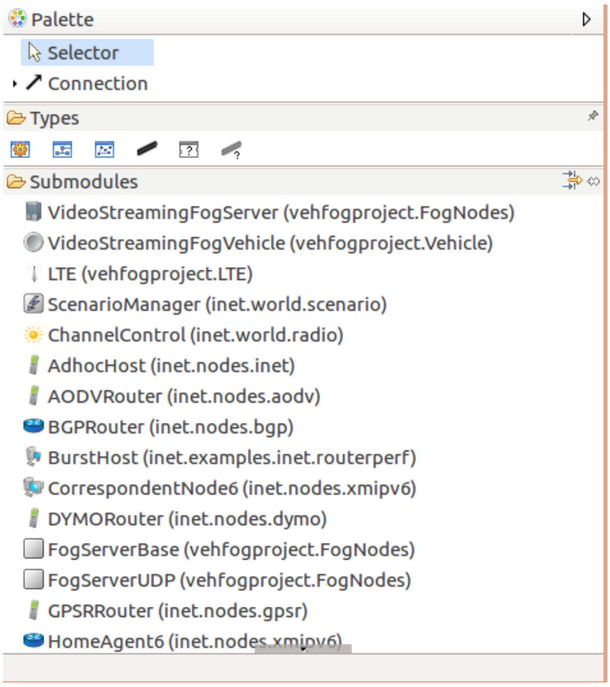


Figure 4.9: palette of omnet++

The topology (VehFogNodeScenario) is composed of many simple and compound modules, the vehicular nodes, ClusterControl, and other nodes of the INET platform, channelControl, confi-gurator and scenarioManager.

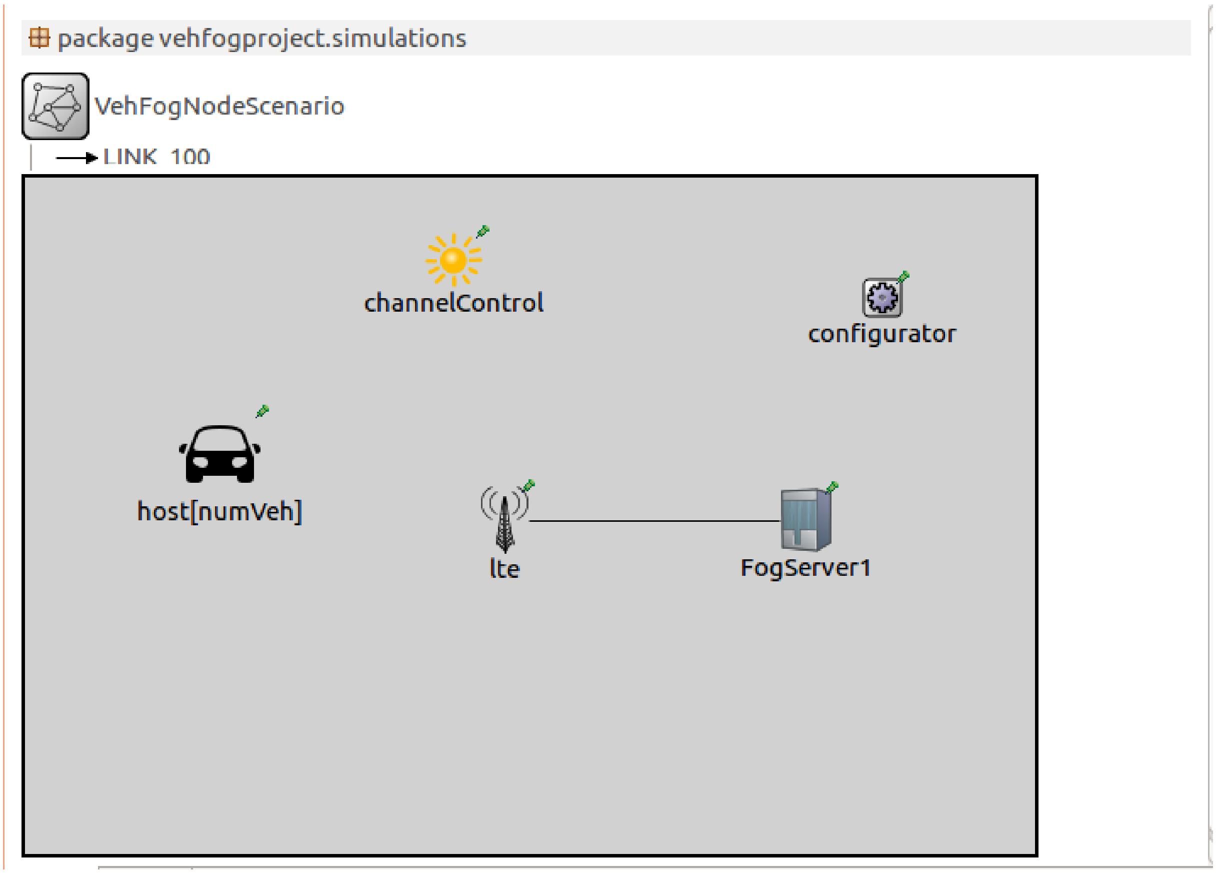


Figure 4.10: The topology of our project

4.5.1 Channel management

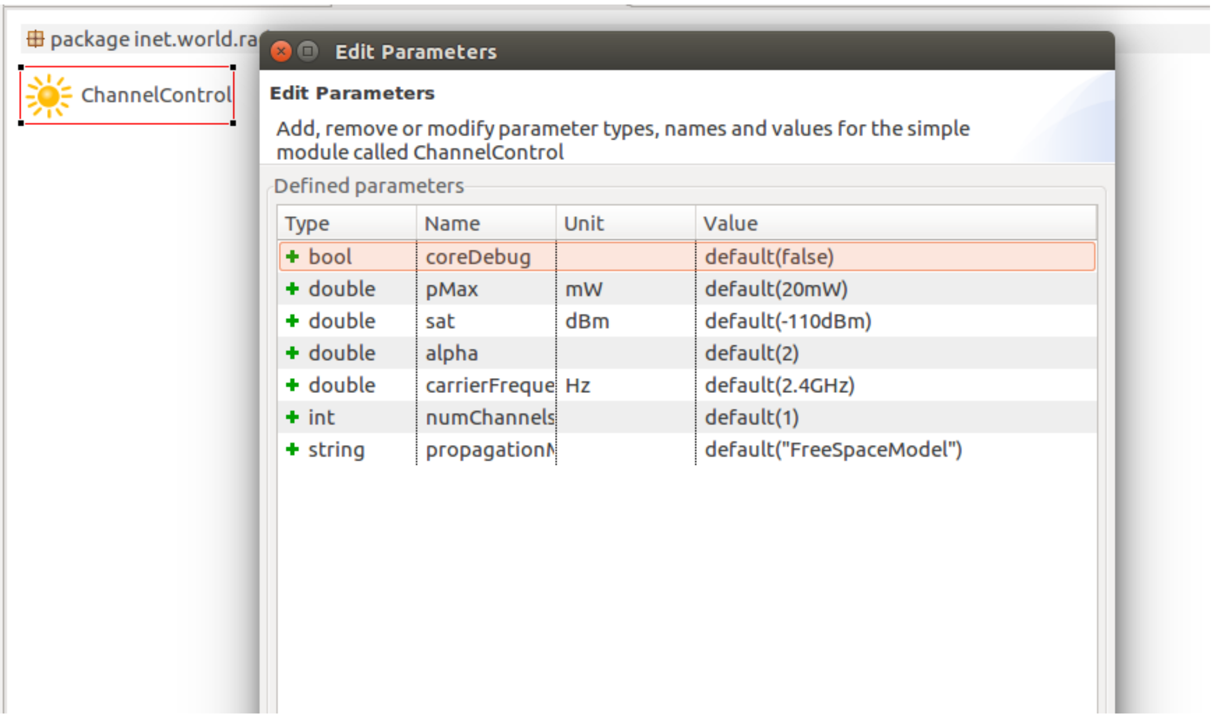


Figure 4.11: ChannelControl

Channel management ChannelControl has exactly one instance in every network model that contains mobile or wireless nodes. This module gets informed about the location and movement of nodes, and determines which nodes are within communication or interference distance. This info is then used by the radio interfaces of nodes at transmissions. Must be named as "channelControl" inside the network.

4.5.2 IPv4 Network Configurator

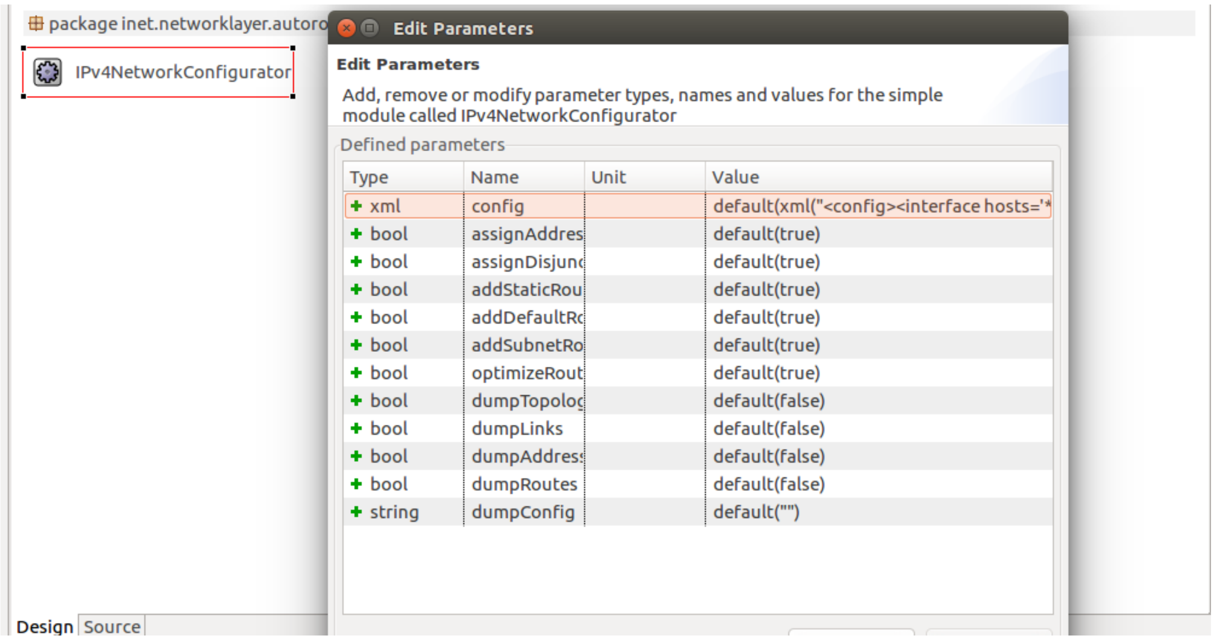


Figure 4.12: IPv4NetworkConfigurator

Configurator his module assigns IP addresses and sets up static routing for an IPv4 network. It assigns per-interface IP addresses, strives to take subnets into account, and can also optimize the generated routing tables by merging routing entries.

Hierarchical routing can be set up by using only a fraction of configuration entries compared to the number of nodes. The configurator also does routing table optimization that significantly decreases the size of routing tables in large networks.

4.5.3 LTE Acess point

Long Term Evolution (LTE) network infrastructure are many LTE identifiers that help move things along, as it is responsible for connectivity requests, which basically means it's the one left asking for permission when it comes time to connect to another network.

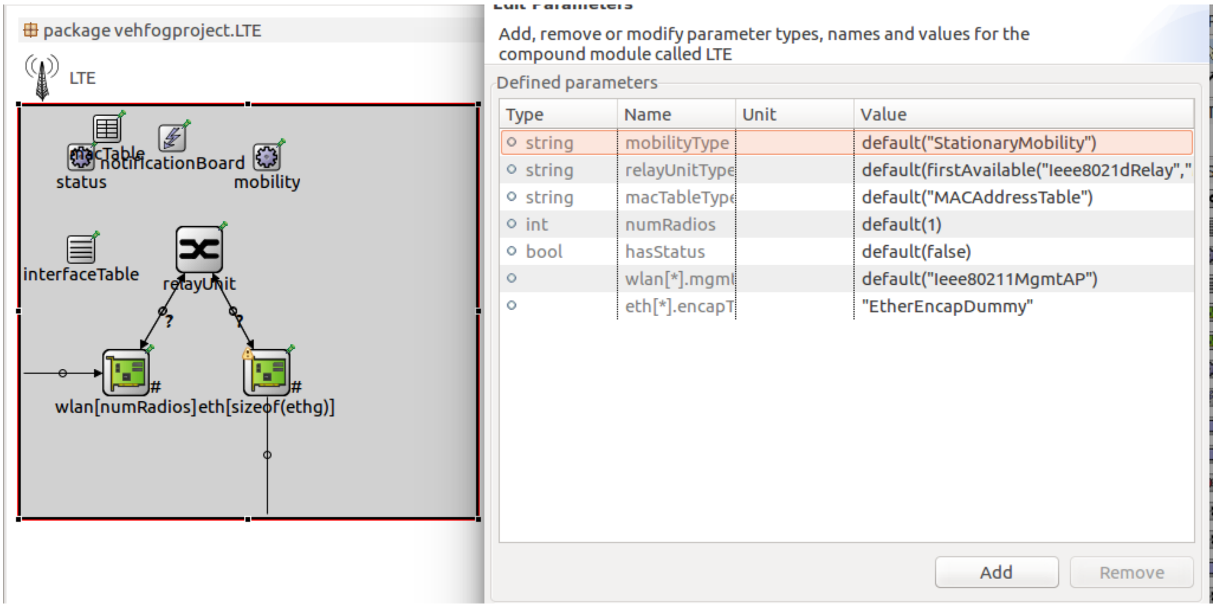


Figure 4.13: LTEaccesspoint

4.5.4 fog server

contains the application of Video stream server. To be used with UDPVideoStream-Client. 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.

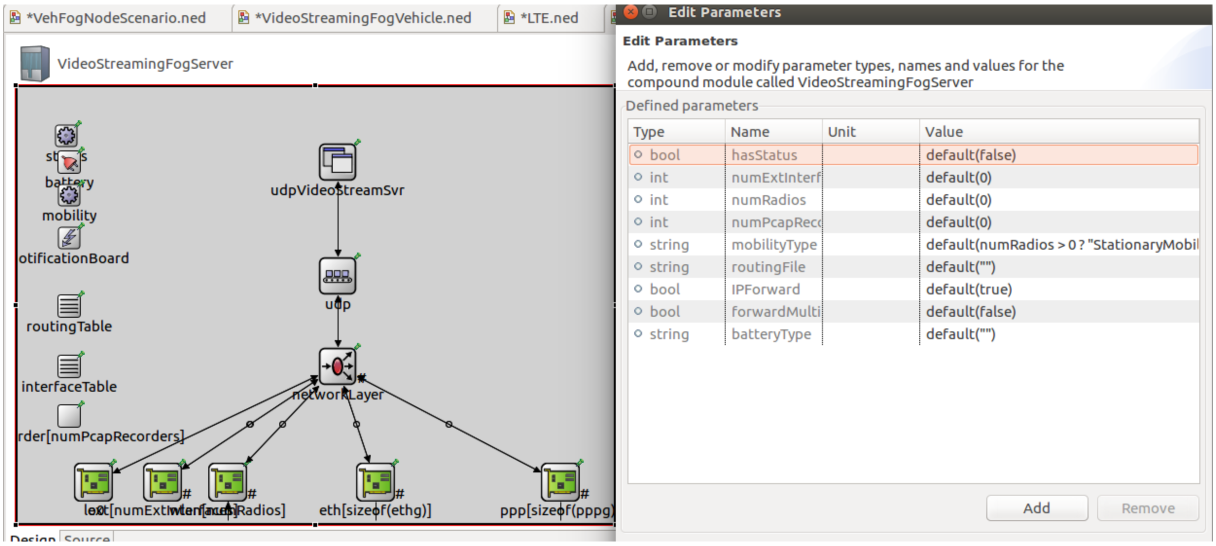


Figure 4.14: Fog Server

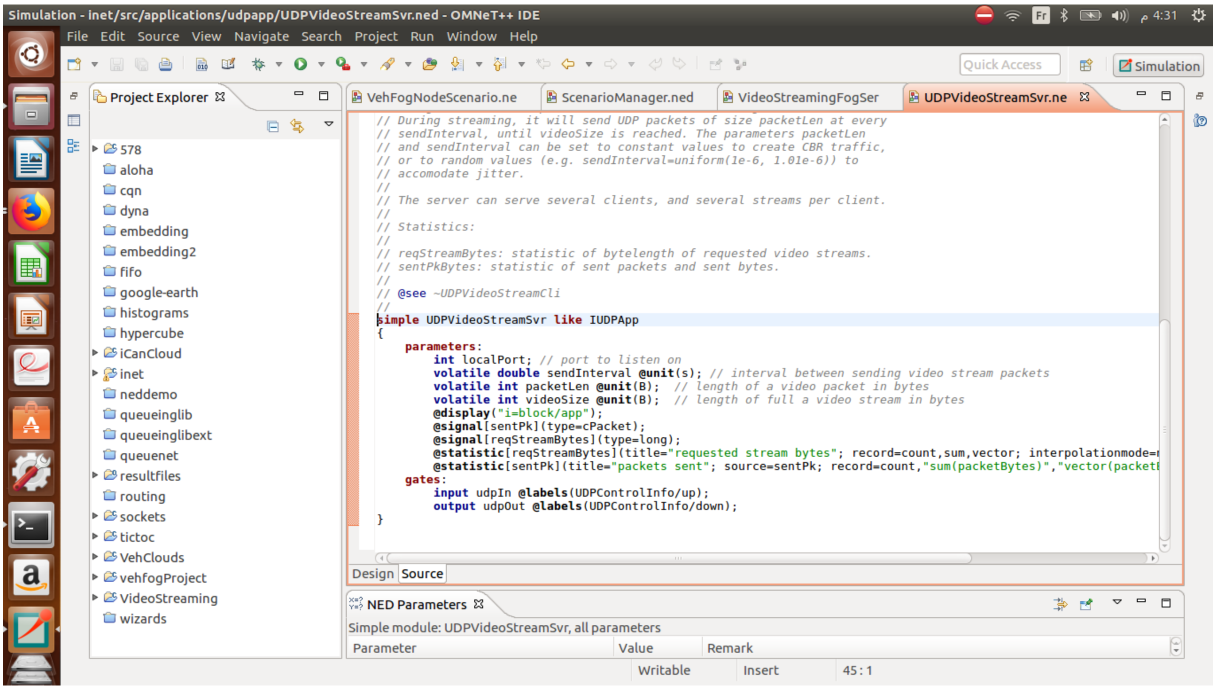


Figure 4.15: UDP video streaming packet(Server)

4.5.5 Vehicular fog node

The vehicle is a module composed of a set of modules either simple or composed, part of the Cloud Computing extracted from iCanCloud; osModule, StorageSystem, memory, and UDP application ,TCP applicaion cpuModule, and other INET module; tcp, networkLayer, DSRC, mobility, routingTable, interface-Table and energyMeter.

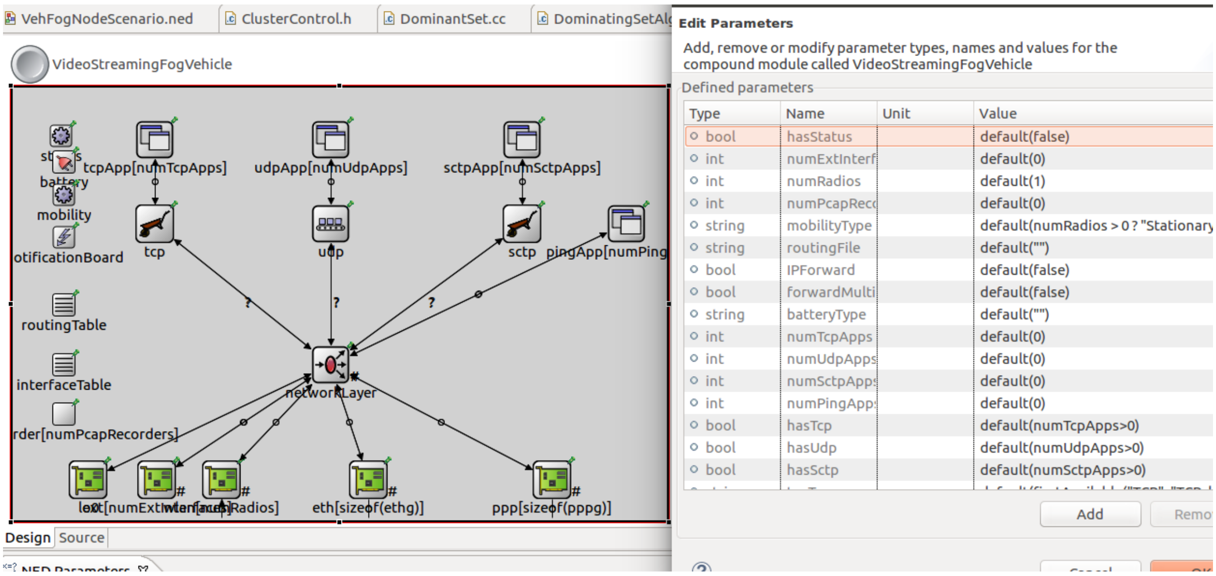


Figure 4.16: Vehicular Fog Node

4.5.6 Scenario manager

ScenarioManager is for setting up and controlling simulation experiments. You can schedule certain events to take place at specified times, like changing a parameter value, changing the bit error rate of a connection, removing or adding connections, removing or adding routes in a routing table, etc, so that you can observe the transient behaviour.

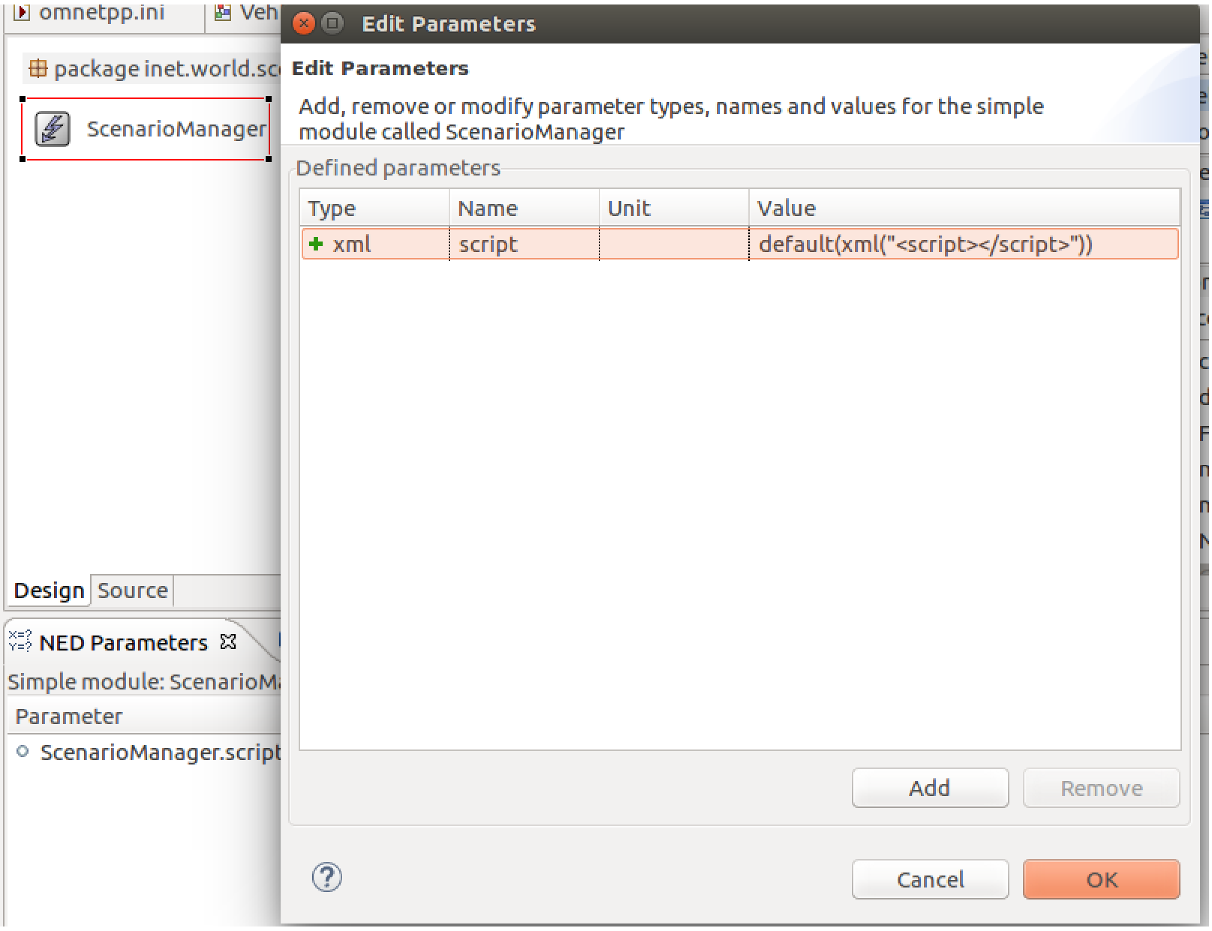


Figure 4.17: scenario manager

4.6 Simulation

4.6.1 Simulation parameters

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)

Table 4.1: Parameters of simulation

4.6.2 Start the simulation

Once you have completed the previous steps, you can start the simulation by selecting omnetpp.ini in the project explorer, then pressing the Run button.

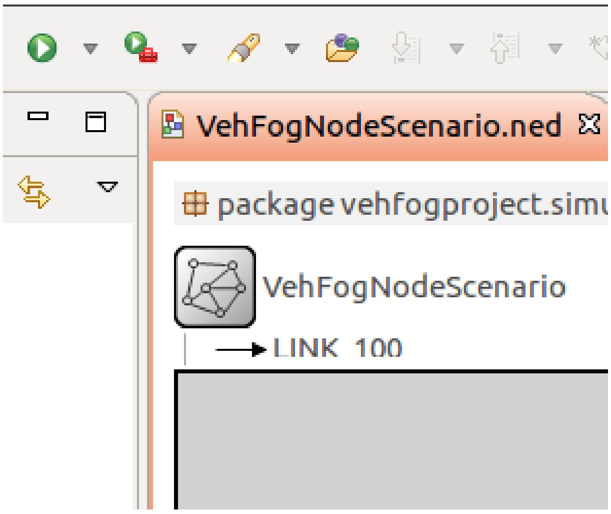


Figure 4.18: Launch the simulation

The IDE Building your project automatically. If there are compilation errors, you must- Please correct them until you get an error-free compilation and link. You can trigger manually build by selecting Project -¿ Build All from the menu or by pressing Ctrl + B. After successfully building and launching your simulation, you should see a new graphics window, similar to the one in the screenshot below. You should also see the network containing the nodes displayed graphically in the main area. Press the Run button on the toolbar to start the simulation. What you should see is that vehicles are exchanging messages with each other.After the Simulation Run, the vehicle nodes will be initialized, afterwards, one of the nodes send a message via a radio interface.

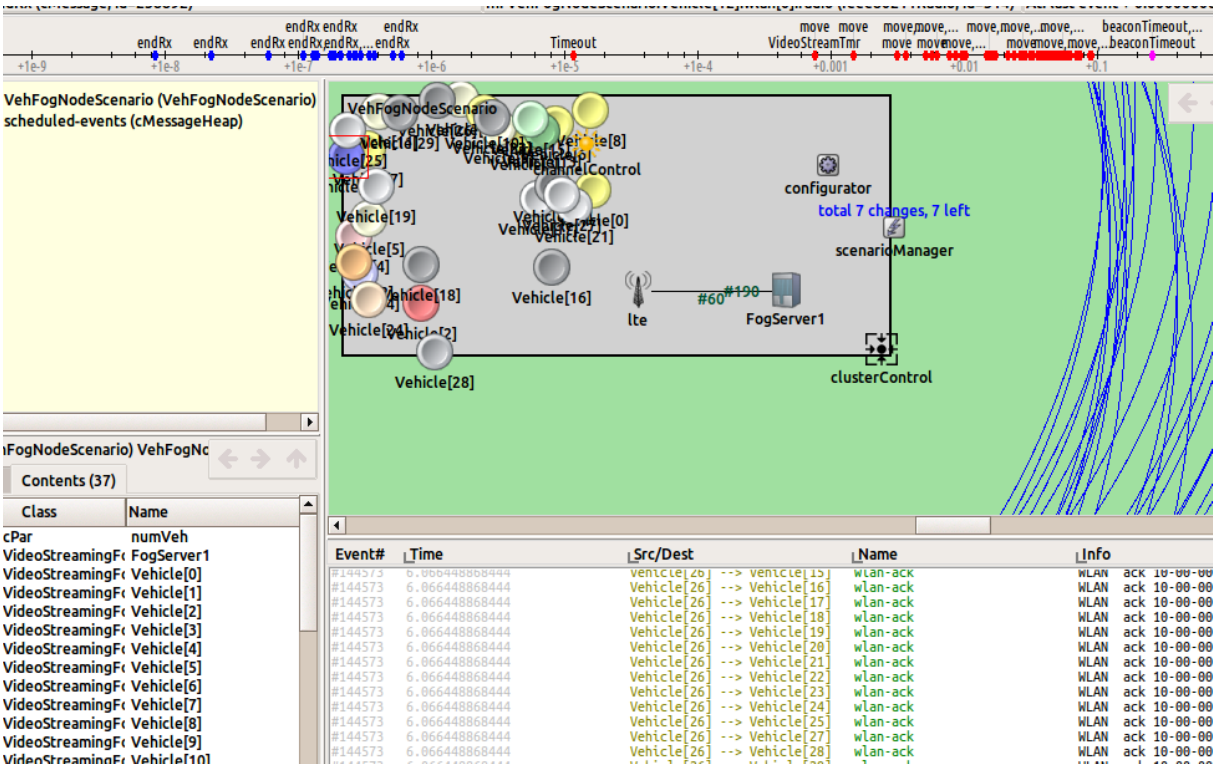


Figure 4.19: run the simulation of video streaming

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 4.19)

4.7 performance analysis

4.7.1 Turning on ACKs

Acknowledgement (ACK) is a radio signal that is passed between topology nodes, or devices to signify acknowledgement, or receipt of message, as part of a communications protocol.

Goals

In this step, we try to make link layer communication more reliable by adding acknowledgments to the MAC protocol.

The model

We turn on acknowledgments by setting the useAcks parameter of CsmaCaMac to true. This change will make the operation of the MAC module both more interesting and more complicated.

On the receiver side, the change is quite simple: when the MAC correctly receives a data frame addressed to it, it responds with an ACK frame after a fixed-length gap (SIFS). If the originator of the data frame does not receive the ACK correctly within due time, it will initiate a re-transmission. The contention window (from which the random back-off period is drawn) will be doubled for each re-transmission until it reaches the maximum (and then it will stay constant for further re-transmissions). After a given number of unsuccessful retries, the MAC will give up, discard the data frame, and will take the next data frame from the queue. The next frame will start with a clean slate (i.e. the contention window and the retry count will be reset).

This operation roughly corresponds to the basic IEEE 802.11b MAC ad-hoc mode operation.

Note that when ACKs (in contrast to data frames) are lost, re-transmissions will introduce duplicates in the packet stream the MAC sends up to to the higher layer protocols in the receiver host. This could be eliminated by adding sequence numbers to frames and maintaining per-sender sequence numbers in each receiver, but the CsmaCaMac module does not contain such a duplicate detection algorithm in order to keep its code simple and accessible.

Another detail worth mentioning is that when a frame exceeds the maximum number of retries and is discarded, the MAC emits a link break signal. This signal may be interpreted by routing protocols such as AODV as a sign that a route has become broken, and a new one needs to be found.

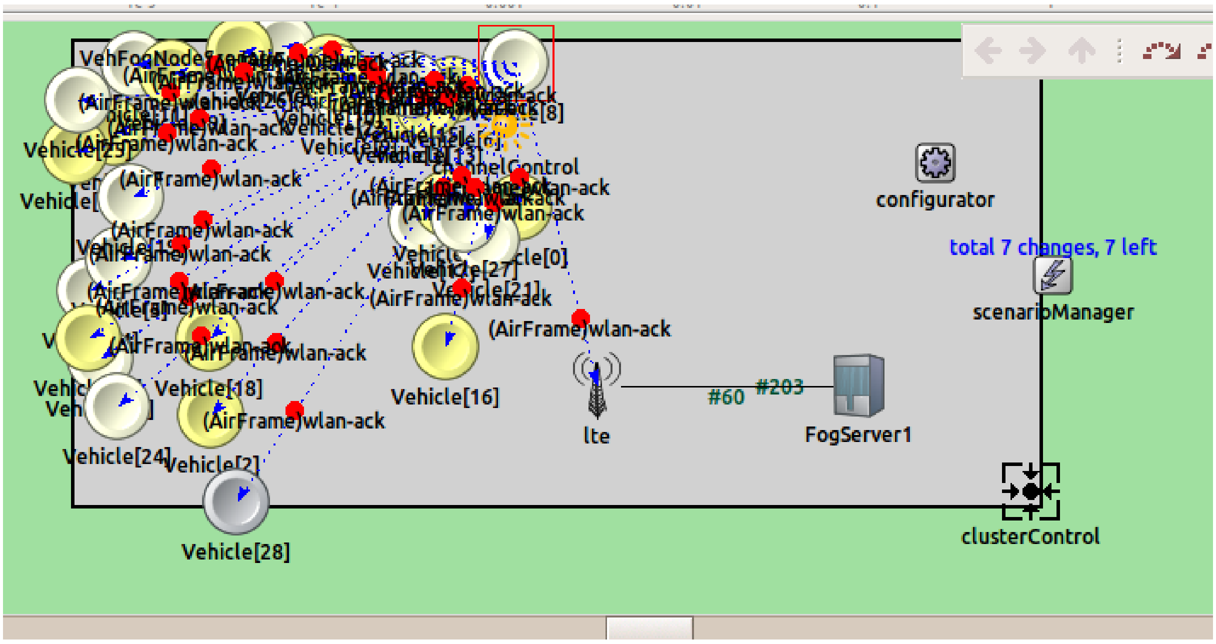


Figure 4.20: Wlan-ack messages

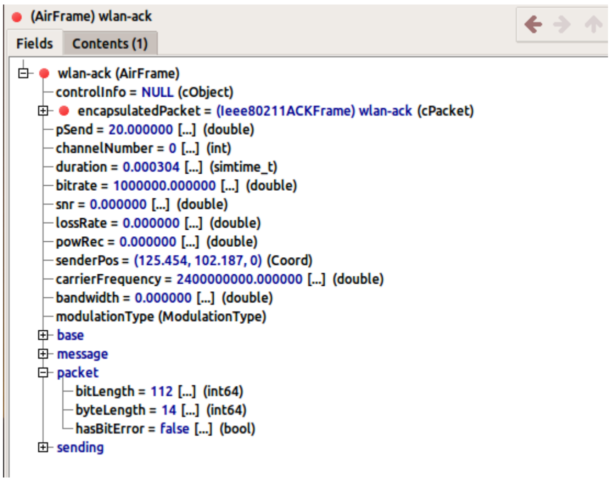


Figure 4.21: Wlan-ack contents

Video streaming packets

At the beginning, vehicles sends a VideoStrmReq packet, requesting the video stream. In response to this, Fog Server starts to send video stream packet fragments to vehicles. The packets are fragmented because their size is greater than the Maximum Transmission Unit. 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 VideoStrmPk-frag1 is received by vehicles, the packet is reassembled in and is sent to the upper layers. As a result of this, a green arrow is displayed between videoServer and person1, representing data link activity at service level.

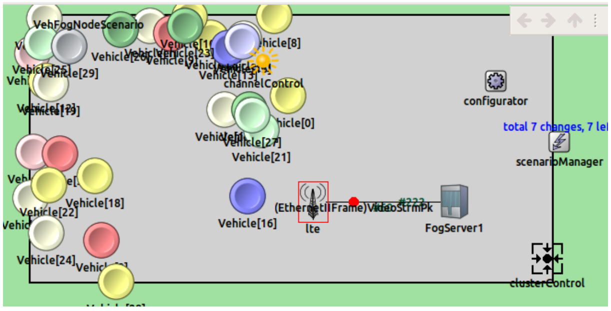


Figure 4.22: VideoStreamPKT

in this figure fog server stream a packets video to LTE. .

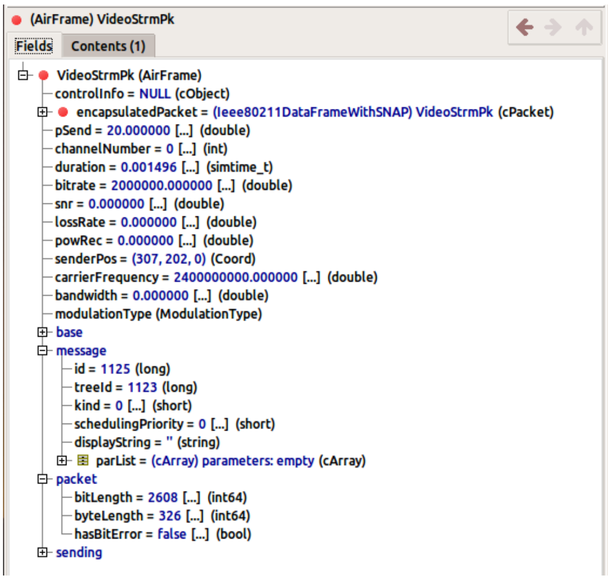


Figure 4.23: videoStrmPk message

in next figure shows that LTE forward video packet that received from fog server to all vehicles in the network.

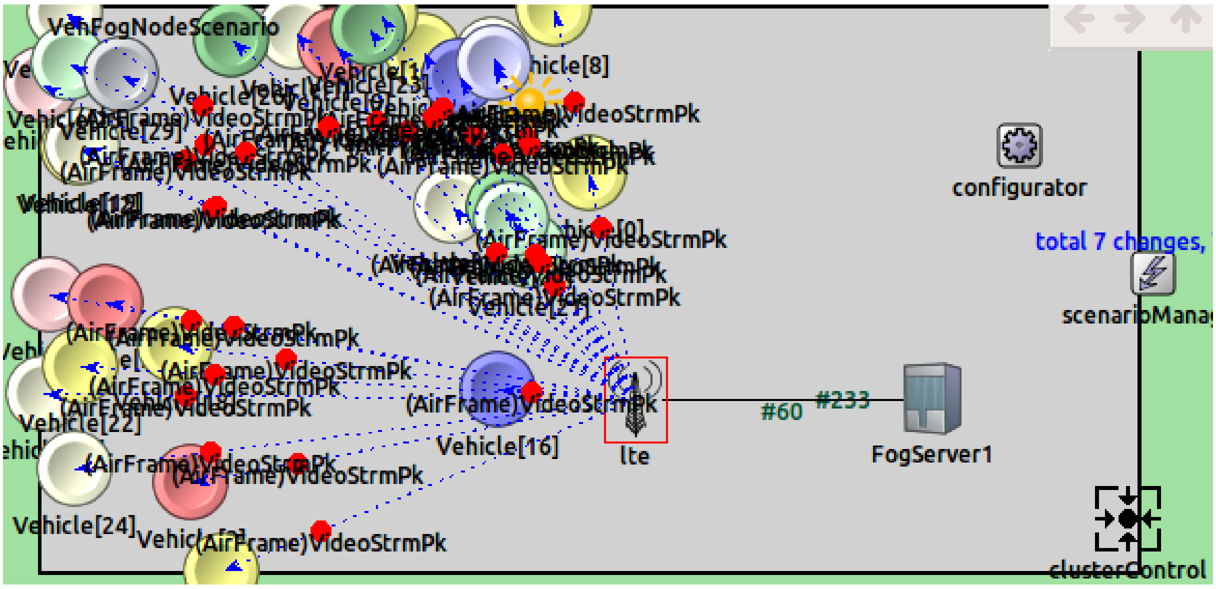


Figure 4.24: VideoStreamPKT to all vehicle

4.7.2 graph results

radio state

The radio model describes the physical device that is capable of transmitting and receiving signals on the medium. It contains an antenna model, a transmitter model, a receiver model, and an energy consumer model.

The following diagram shows usage relationships between types.

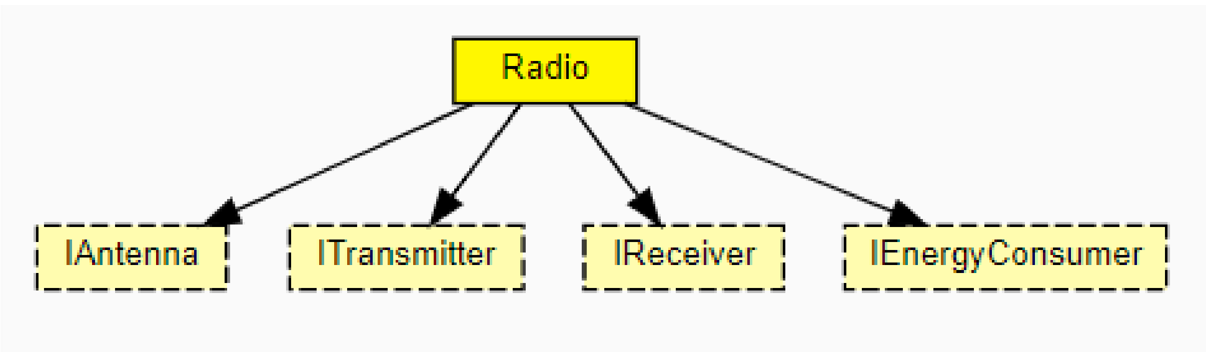


Figure 4.25: Usage diagram

The radio model supports changing radio mode, transmission power, or bitrate.

next figure shows radio state changes in our simulation.

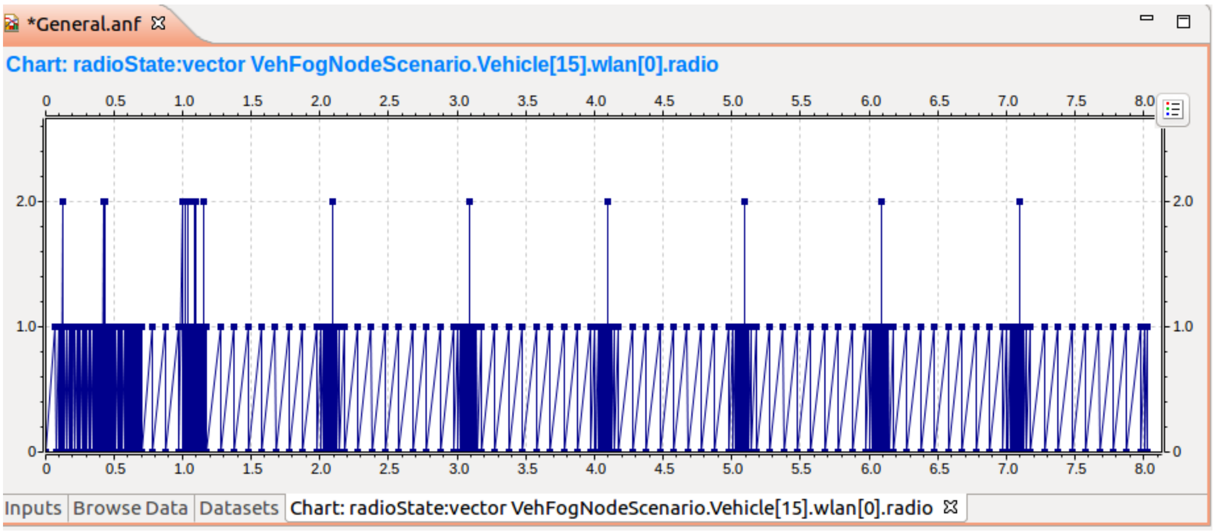


Figure 4.26: Radio state graph

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

Packet Sent To Lower

AckingMac This module implements a trivial MAC protocol for use in AckingWireless-Interface.

The implementation provides packet encapsulation and decapsulation, but it doesn't have a real medium access protocol. It doesn't provide carrier sense mechanism, collision avoidance, collision detection, but it provides optional out-of-band acknowledgement. Higher layer packets should have MacAddressReq tag.

The following diagram shows usage relationships between types.

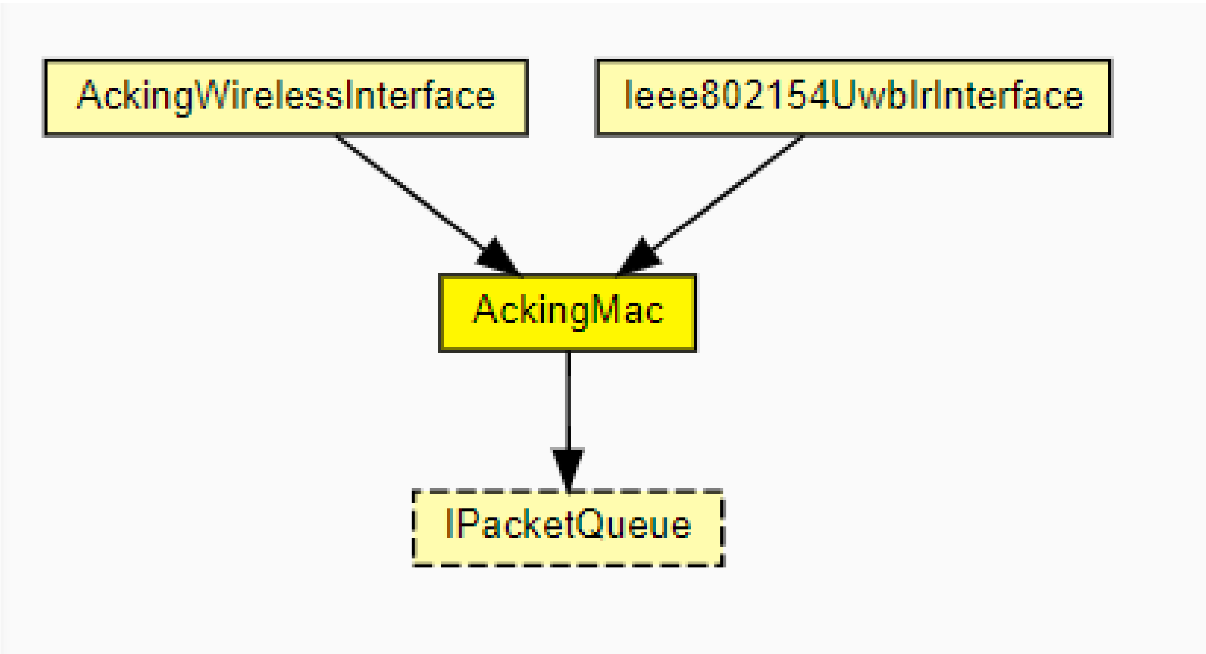


Figure 4.27: Sent down packets

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

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 nodes of network but the rest of simulation we see that sent down packets is also balanced and there is no latency despite the mobility of nodes.

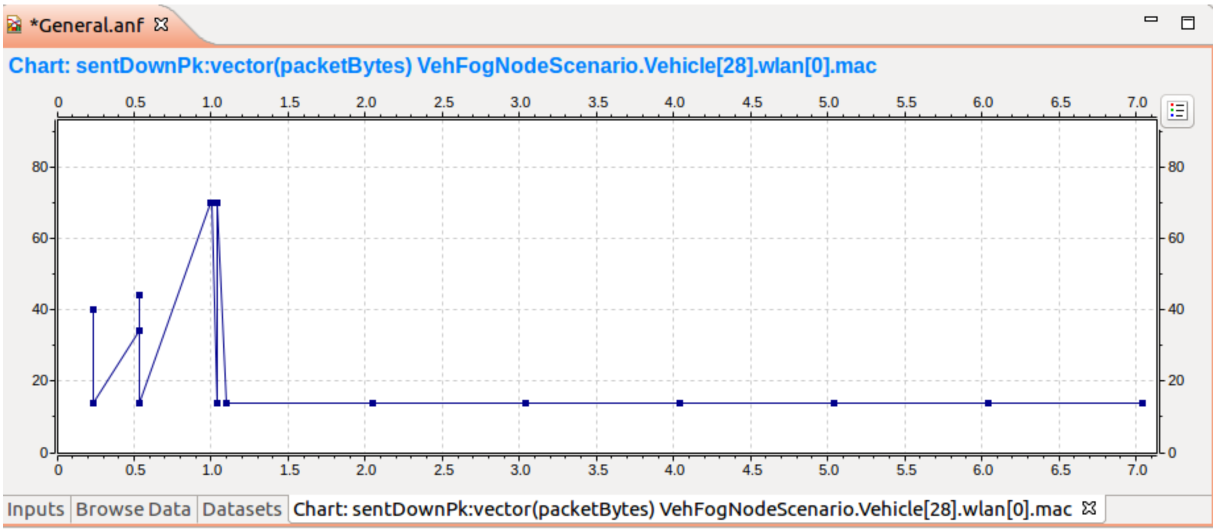


Figure 4.28: Sent down packets

End to end delay

In this section, we examine how routing packets affects the end-to-end delay of packets. The length of packet queues in the MAC can significantly affect delay, as packets can wait in the queue for some time before being sent. If the traffic is greater than the maximum possible throughput, queues are going to fill up, and the delay increases. If traffic is less than the maximum possible throughput, queues won't fill up (no increased delay), but the performance would be less than the maximum possible. If traffic is the same as the maximum possible throughput, the performance is optimal, and the delay is minimized (we configured traffic this way).

The lowest delay in next graph because the packets don't wait in the queue as much to be part of an aggregate frame. With the best effort priority aggregation, the delay is higher. The multiple data points above each other signify the reception of an aggregate frame, as the packets making up the aggregate frame are sent to the UDP app at the same time. The earliest packet in the aggregate frame has been in the transmission queue for the longest, so it has the most delay. because the MAC waits less before acquiring the channel when sending the packets.

the previous graph shows that End to End Delay is also in the first step of simulation is heavy due to the process of beaconing exchanged between all nodes of network 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.

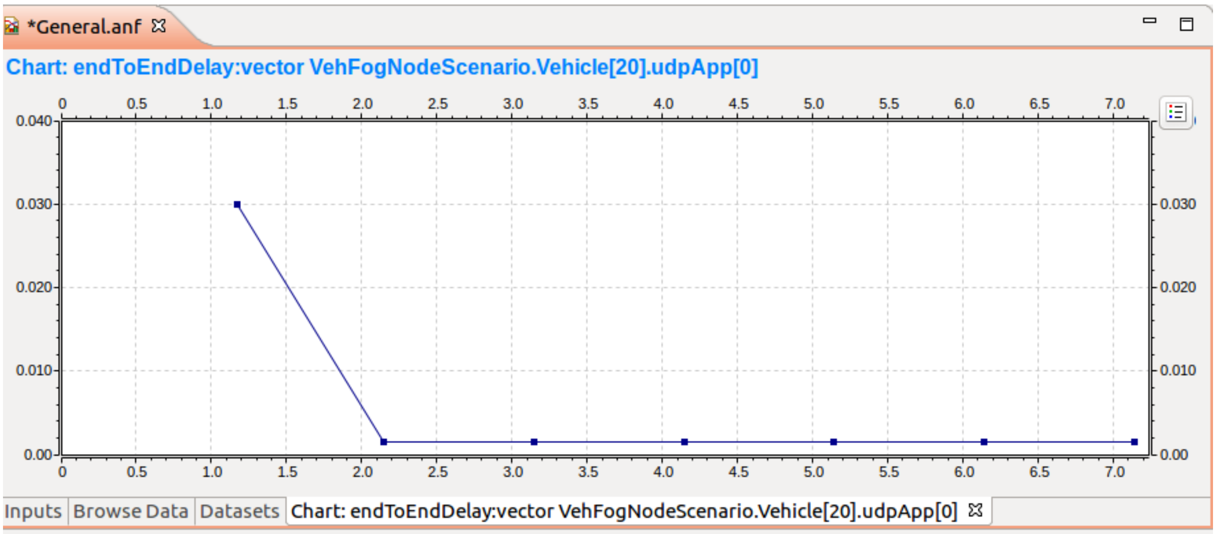


Figure 4.29: End to end delay

4.8 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 works well and improve performance as we seen in the results such as low latency radio state almost steady and its principle is based on four basic steps which are:

- Extraction of sub networks.

- Extraction of links.

- The dominant group calculates.

- The colorization of the nodes.

- Disseminate video packets

The aim of this approach is to set up the difference between the different calculus nodes and storage, also reduce the latency using fog computing technology in our application for video streaming.

General Conclusion

We recall that the main objective of this thesis is to implement an approach that uses fog computing technology for data scheduling, where the video streaming application is a practical use case. 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 Omnettpp simulation model.

At the beginning, we presented the vehicular networks; its components, its characteristics and various vehicle applications. Then, we describe the different types and strategies of data dissemination in VANET. After that, we presented the integration of Cloud Computing in VANET networks with main problems of VANET cloud applications. Finally, we give an overview of vehicular fog computing.

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 we discuss the works cited in this approach deal with the problem of video streaming over vehicular networks,our strategy like the other strategies that have been to propose,our contribution in this area taken 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, the architecture of the model. At the end of the chapter, we present the algorithms implemented network.

Finally, in the last chapter, we present our simulation project, the implementation of the different algorithms, functions, Cluster Control module. Then, we describe the simulation scenario and the different simulation steps and results. At the end, we extracted the simulation statistics.

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.

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