A Virtual Clustering for Data Dissemination in Vehicular Fog Computing

Philippe Roose, Sahraoui Abdelatif, Abdelhak Ghouzlen

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Sahraoui Abdelatif
University of Larbi Tebessi
dept. Mathematics and computer science
Tebessa, 12000, Algeria
abdelatif.sahraoui@univ-tebessa.dz

2nd Philippe Roose
LIUPPA/UPPA
2 Allée du Parc Montaury,
Anglet, 64600, France
Philippe.Roose@iutbayonne.univ-pau.fr

3rd Abdelhak Ghozlane
University of Larbi Tebessi
dept. Mathematics and computer science
Tebessa, 12000, Algeria
hakougho22@gmail.com

***Abstract*—The concept of data dissemination has become an inherent problem with Vehicular Ad hoc NETwork (VANET), especially when traffic jams occur. The main idea of data dissemination is how to handle a huge amount of traffic data collected in the vicinity. Therefore, different strategies have been proposed by the research community in this field to solve this problem, including routing protocols, virtual machines, data aggregation, clustering and so on. In this paper, a virtual cluster strategy is proposed to select candidate vehicles acting as getaways in the network. In particular, the formation of the virtual clusters is based on dominant set algorithm to create virtual network for data dissemination. In the evaluation phase, the simulation results demonstrate the effectiveness of the proposed clustering strategy to significantly improve network performances.**

***Index Terms*—Data dissemination, virtual cluster, dominant set, vehicular fog computing**

I. Introduction

The Vehicular Ad hoc NETwork (VANET) as a subclass of Mobile Ad hoc NETwork (MANET) is deployed to increase safety on the road and provide a comfortable aspect for drivers. Since road safety has strict requirements, it is not easy to design, implement and deploy safety applications that work well on on-board units and on a wide range of wireless networks. However, critical scenarios in vehicular networks are challenged by the sporadic nature, unreliable communication links between nodes, limited performance in terms of bandwidth, a high error rate, a higher latency.

To face these challenges, it should rethink traditional approaches in order to facilitate their design, taking into account the constraints of vehicle mobility for data processing and communication. Recent change made by the automotive industry are investing in the supply of smart vehicles with sophisticated integrated components, powerful computing and high-capacity storage. This convergence allows vehicles to collaborate to detect the environment, share their traffic data on the move, control traffic flow, communicate wirelessly with the cloud and other vehicles. The advent of Vehicular Cloud Computing (VCC) paradigm allows vehicles to request traffic information anywhere and anytime. The most important features of VCC are to create dynamic clouds in vehicular networks, namely Vehicular Clouds (VC), VANET-Clouds (VuC) and Hybrid Vehicular Clouds (HVC) [1]. These frameworks are eager to solve the inherent problems accumulated in vehicle networks, such as increased message latency, message efficiency and insufficient throughput.

Additionally, it provides traffic services and disseminate safety information, data notification, data decision, to vehicles and drivers stuck in real-time traffic. These safety applications could provide information on a large vehicular network compared to disseminated information provided by a traditional vehicular network or by the traditional cloud services. For example, a parked vehicle is a VC scenario that offers stable and long-term availability of vehicle resources where, during working days, employees park their vehicles for hours in the parking lot. In this scenario, the vehicle occupation time is managed by an open source CC architecture called ”Eucalyptus” where the client-side API communicates with the Cloud controller, the node controller, several cluster controllers. Planning dynamic traffic lights to overcome heavy traffic is another scenario where dynamic cloud are used. basically, the performance of traffic lights would not be effective when a major event occurs. An effective collaboration between vehicles and road infrastructure will help solve this problem in a timely manner.

In the previous scenarios, improving data dissemination strategies is mandatory to ensure efficient network performance in the future of traffic systems. The data dissemination can range from cluster-based routing to virtual machine (VM) migration. Cluster-based routing is a crucial data dissemination strategy that can be used by safety applications to optimize the performances of the VANET network. The vehicle cluster is a subset of vehicles grouped together according to the dynamic characteristics of the network topology. Using clusters dramatically improves network performance by limiting network traffic between clusters.

During peak hours when traffic is heavy, vehicles generate massive traffic data with important information to transmit. Due to the high mobility of vehicles, the network is frequently intermittent where vehicles can join and leave quickly, making designing an effective data dissemination strategy a great challenge. These factors lead to unstable clustering when transmitting packets between one or more clusters.

In this paper, a virtual cluster strategy is proposed to improve data dissemination in vehicular fog computing environments. The selected virtual nodes are subsets of vehicles that provide stable vehicle clusters, adapt to intermittent networks and high vehicle mobility. In particular, the formation of the virtual nodes is based on a dominating set algorithm to create a virtual data dissemination network.

II. Related work

In Vehicular Cloud Computing (VCC), it is imperative to disseminate data in the vehicular network, where traffic data can be disseminated according to uplink and the downlink features. Hence, a certain number of data dissemination strategies have been proposed in VCC integrating routing protocols, data collection and aggregation using virtual machines, physical and virtual clusters.

The main challenge of vehicle routing protocols is how to preserve network bandwidth, broadcast critical traffic data with low overhead and delays. The flooding technique is the conventional traffic data dissemination strategy, where the vehicle source broadcasts a message to all neighbors in its transmission range or when that message is never seen. This technique works well in free traffic conditions, but its performance decreases in congestion conditions where it leads to inefficient data dissemination, from which it results the broadcast storm problem [2]–[5].

In addition, moving vehicles generate a considerable amount of traffic data including critical information about the traffic to be disseminated. Although these massive data are supported by advanced VANET applications and aims to increase road safety by providing multiple types of traffic data for vehicles, it requires an efficient data collection process. Thus, it consumes a large amount of bandwidth which causes most traffic applications not to coexist, this is another fundamental challenge for vehicle routing protocols. In order to reduce the communication overload and save bandwidth for large-scale traffic data dissemination, either traffic data aggregation or clustering are solutions. In conventional approaches, the design an efficient data collection and aggregation is based on a set of spatio-temporal traffic flow parameters (e.g., speed, density, travel time, etc.) and networks parameters (e.g., latency, bandwidth, end to end delay, etc.) [6]. Whereas, vehicular cloud applications aim to guarantee better network performances and serve a large number of traffic applications through available bandwidth and efficiently manage vehicle/RSU resources for computation and storage. Patre et el. [7], propose resources management approach in order to serve a large number of traffic applications requests. The simulation shows reliable performances in terms of average response time, served application requests and the number of virtual machine (VM) migration. Jelassi and Bouzid. [9], propose a roadside cloudlet for scheduling video content upon vehicle request. In order to ensure continuous streaming sessions, the dissemination of video content is based on installed set of VMs, acting as streaming servers, on the roadside cloudlet.

III. Vehicular fog computing architecture for data dissemination

This section explains our proposed Vehicular Fog Computing (FCV) architecture for intelligent traffic applications, the key functionality of each component, it supports the power of computing of the fog servers, the position of each vehicle in the topology and position of the base stations in order to provide an effective data dissemination strategy. Particularly, the architecture that we propose is based on three essential layers: the connected vehicles layer, the traffic Fog layer and the cloud services layer, as shown in the figure 1.

The *connected vehicles layer* is closest to the vehicles and the drivers. It consists of connected vehicles and its drivers, sensors, base stations, cellular antenna, etc. In our data dissemination strategy, only connected vehicles and base stations are considered.

The *traffic Fog layer* is located as an intermediate layer of a network, it consists of connected vehicles (selected as virtual nodes in our data dissemination strategy) and traffic Fog servers. This layer may include also several types of access points, LTE, etc. In our proposed architecture, connected vehicles selected as virtual cluster, access point, LTE, base stations are play an important role for the proposed data dissemination strategy. The traffic Fog servers are attached to specific locations in city and communicate with base stations and LTE using wired communication. In addition, these servers are described for processing traffic data and collect data from the connected vehicles layer, fast data storage or broadcast received traffic messages from upper layer (cloud layer) to the vehicles.

The essential role of the *cloud layer* in our architecture is to provide traffic cloud services such as vehicle resource allocation, storage, analysis and processing of traffic data, to each vehicle node and to each traffic server. Additionally, these cloud services control and offload the traffic workloads on the fog layer.

In what follows, we will present an overview of the main components of the proposed architecture illustrated in the figure 1. These components are:

The *vehicle* is equipped with a GPS device, an on-board unit (OBU), several types of sensors, dual interfaces to provide access to cellular networks, a radio transceiver module to provide access to the conventional VANET standards (such as WAVE). Using this large game of embarked equipments, each vehicle can sense its current position and share it with its neighbors using V2V and V2I communications.

The *base stations (BS)* are crucial components on the vehicular ad hoc network. Unlike to conventional base stations, our architecture supports BSs equipped with powerful servers to provide real-time storage, computing, real-time communication with traffic Fog servers. These BS are used to collect traffic data and detect accurate location of vehicles in real time.

The *traffic sensors* are used to collect real-time traffic information, measure traffic parameters such as traffic flow, traffic speed, traffic density, road occupancy.

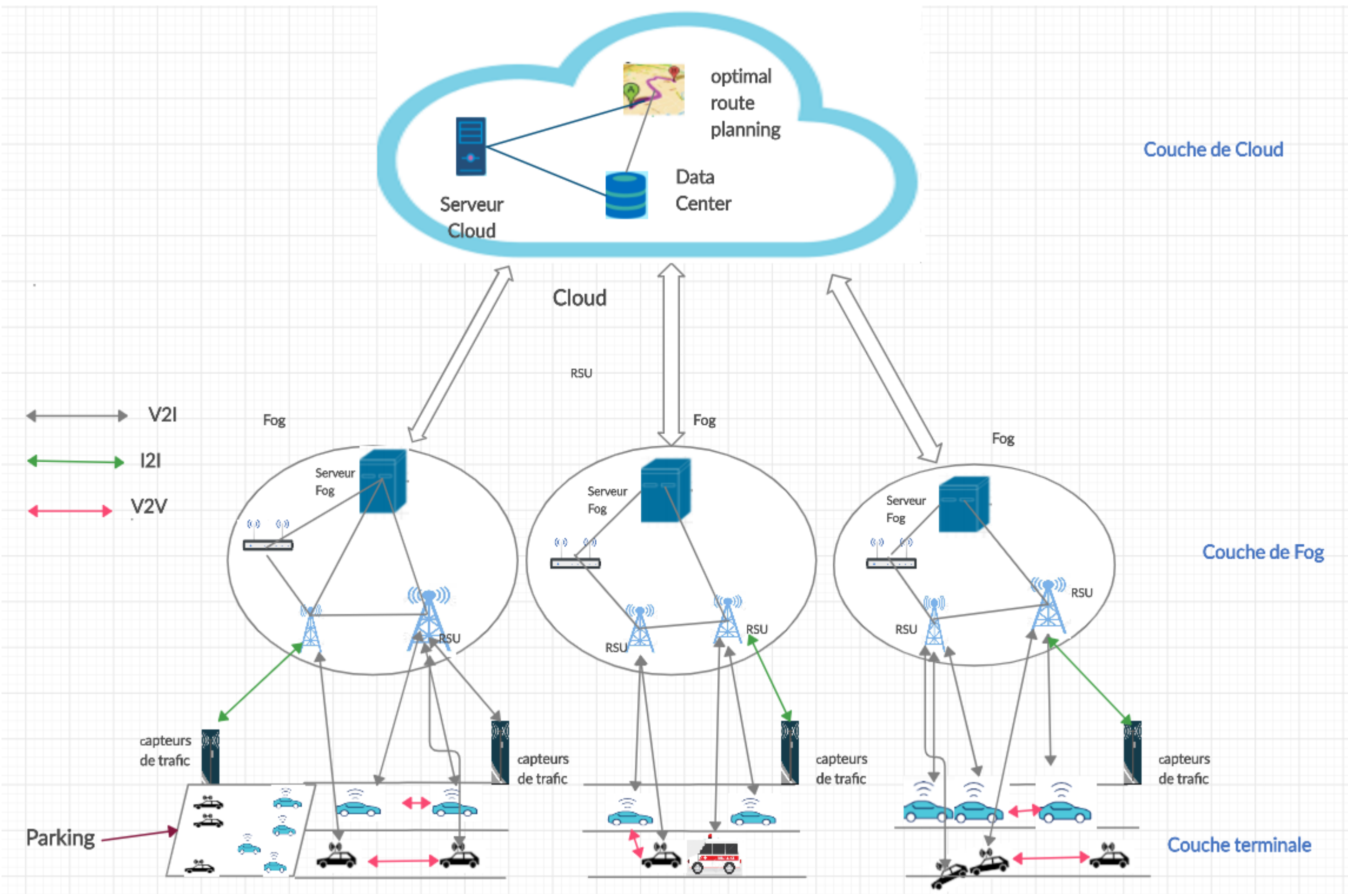


Fig. 1. The proposed vehicular Fog Computing (FCV) architecture with three layers.

IV. Virtual clustering for adaptive traffic applications

In most vehicular traffic scenarios, there is a large amount of useful information to inform drivers when an event occurs (accidents, traffic jams, works, emergency braking, available parking spaces, presence of speed cameras, etc.). police, 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 the context of ”collaborative driving” and that other of this information is recorded.

To add significant value to these technologies and make these networks more useful, vehicular fog services are offered where vehicles become capable of performing calculations using a base station, saving data and information in a storage space installed on the vehicles, all these services make the simple vehicles of the Cloud vehicles, and to ensure reliable and efficient communication between the vehicles, a DSRC interface is added, this interface ensures the RADIO communications, Thus, with the integration of cloud services, simple VANETs become cloud VANETs.

A. Vehicular network traffic clustering

In our architecture, vehicles close to each other form a cluster, each cluster has a Cluster Head. In our architecture, we use cluster heads for the computing operations, and instead of having a single cluster head, we choose several members among the cluster to make the computation. The choice of these members is done by the algorithm of the dominant groups (Dominating Sets Algorithm [8]). The figure 2 show our adapted dominant set algorithm for vehicular traffic data dissemination. Given that the vehicular networks are known by their dynamic mobility, the formation of clusters is a effective solution for maintaining 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 in charge of creating the cluster must be an adaptive application and take into account that the node that leaves a group must in enter another if it meets the conditions.

B. Adaptative VANET applications

Wireless communications and the on-board unit of the vehicles allow conductors to access information anywhere, anytime. In which, the designing, implementing and deploying traffic applications that work well on all vehicles and on a wide range of wireless access networks is no small feat. Because the

```
Variables
i,j : Integer
vis[100011] : bool
graph : Table[Table [Integer]]
Table(Integer) solve_dominant(node Integer,edge Integer)

Begin
    Table(Integer) S;
    for i = 0 to i<=nœud do
    Begin
        if (vis[i]= false)
            begin
                if  S←S+i then
                begin
                    vis[i]←vrais;
                    For j = 0 to graph[i]. lenght() do
                        Begin
                            if (vis[graph[i][j]]= false)
                              Begin
                                    vis[graph[i][j]]←true;

                              End if
                             j←j+1 ;
                        End For
                End if
                i←i+1 ;
    End for
            return S;
End
```

Fig. 2. Adaptation of the Dominant Set algorithm for vehicle traffic data clustering.

network connections in vehicular scenarios are characterized by limited bandwidth, high error rate, higher cost. On the other hand, the constraints and limitations faced by vehicular applications are not a product of current technology. But they are naturally linked to mobility and it should rethink traditional approaches for the new design.

V. Simulation and Evaluation

This section shows the performance evaluation of the proposed algorithm for vehicular fog computing environments. The automobile traffic information in our study scenario generally has a broadcast aspect, i.e. it is information of public interest and generally benefits a group of vehicles rather than to a specific vehicle. During vehicle mobility, traffic information needs to be exchanged and recorded between nodes. To select a set of gateway vehicles, we try to use the proposed cluster technique to predict the groups of vehicles sharing the same traffic information or that which form the intermittent networks, as shown in the figure 3. For example, vehicles can exchange traffic control information such as ”coordinates”, ”speed”, ”density”, ”traffic volume”, etc.

After the cluster formation, it is necessary to choose the dominant sets through the application of a “dominant algorithm” to create virtual vehicular networks. The ”dominant sets” ensure the backup of the messages and execute the computational tasks. The connection between the members of the dominating set produces a ”virtual cluster” where each node of this cluster takes a function among the functions of the Fog services, for example (a storage node, a computing node, etc.).

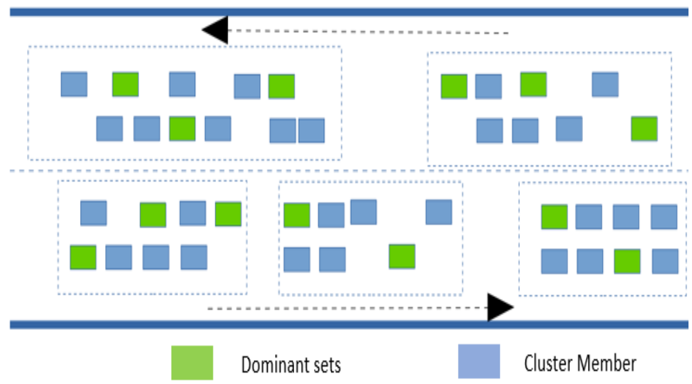


Fig. 3. Cluster architecture

In the simulation step, we realized an extension under Omnet++ [10], including iNet [11] and iCanCloud simulation framework [12] to provide a set of simulation modules for vehicular Fog scenarios (vehicular node, storage node, calculation nodes, etc.) as well as a cluster manager. On the one hand, the simulation modules are equipped with a DSRC interface which ensures the dissemination of traffic information. On the other hand, the cluster manager is for applying the technique of clustering and managing the vehicular traffic.

After launching the simulation, as shown in figures 4 and figure 5 the cluster controller module extracts the different sub networks (SubNet), the number of Subnets and the dominant groups (Dominant Set). According to the initial topology, the cluster control gives a result of four clusters, each one with these members, and because of the mobility of the nodes, the topology is changing, so the places of the nodes change which implies modifications in the clusters, then, the cluster control redefines five new clusters.

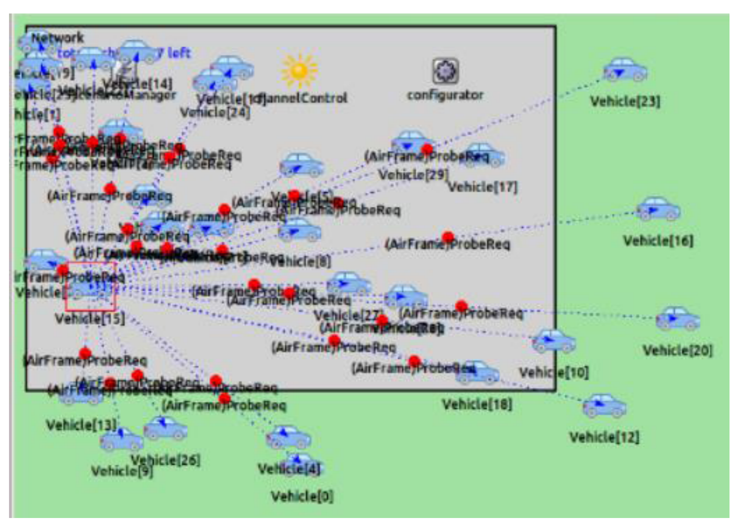
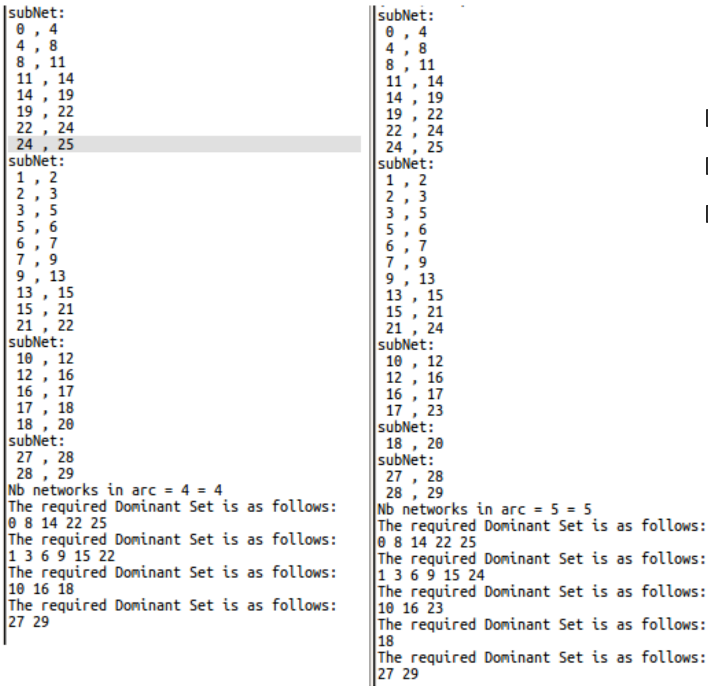


Fig. 4. Traffic data dissemination, an Omnet++ project



```
subNet:
 0 , 4
 4 , 8
 8 , 11
 11 , 14
 14 , 19
 19 , 22
 22 , 24
 24 , 25
subNet:
 1 , 2
 2 , 3
 3 , 5
 5 , 6
 6 , 7
 7 , 9
 9 , 13
 13 , 15
 15 , 21
 21 , 22
subNet:
 10 , 12
 12 , 16
 16 , 17
 17 , 18
 18 , 20
subNet:
 27 , 28
 28 , 29
Nb networks in arc = 4 = 4
The required Dominant Set is as follows:
0 8 14 22 25
The required Dominant Set is as follows:
1 3 6 9 15 22
The required Dominant Set is as follows:
10 16 18
The required Dominant Set is as follows:
27 29
```

```
subNet:
 0 , 4
 4 , 8
 8 , 11
 11 , 14
 14 , 19
 19 , 22
 22 , 24
 24 , 25
subNet:
 1 , 2
 2 , 3
 3 , 5
 5 , 6
 6 , 7
 7 , 9
 9 , 13
 13 , 15
 15 , 21
 21 , 24
subNet:
 10 , 12
 12 , 16
 16 , 17
 17 , 23
subNet:
 18 , 20
subNet:
 27 , 28
 28 , 29
Nb networks in arc = 5 = 5
The required Dominant Set is as follows:
0 8 14 22 25
The required Dominant Set is as follows:
1 3 6 9 15 24
The required Dominant Set is as follows:
10 16 23
The required Dominant Set is as follows:
18
The required Dominant Set is as follows:
27 29
```

Fig. 5. The virtual clusters

VI. Conclusion

In this paper, a virtual cluster strategy is proposed to improve data dissemination in vehicular fog computing environments. The selected virtual nodes are subsets of vehicles that provide stable vehicle clusters, adapt to intermittent networks and high vehicle mobility. In particular, the formation of the virtual nodes is based on a dominating set algorithm to create a virtual data dissemination network.

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