QoS-aware Data Offloading for Vehicular Networks

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Les réseaux véhiculaires échangent divers types de données qui doivent être transmises vers les Road Side Units (RSU) depuis directement depuis les véhicules à portée de communication. Les RSU n'étant pas déployés partout, on observe une connectivité intermittente des véhicules avec les RSU. Dans cet article, nous proposons un schéma d'envoi des données pour les réseaux de véhicules avec QoS (DOVEQ), qui permet à un véhicule de transmettre ses données vers un RSU directement ou via des communications inter véhicules (V2V). DOVEQ prend en compte le temps de connexion d'un véhicule avec le RSU et les autres véhicules se dirigeant dans la même direction ou la direction opposée, la capacité d'envoi et le temps prévu pour atteindre la zone de couverture d'un RSU. De plus, la qualité de service (QoS) est une considération importante pour la transmission de données dans les réseaux de véhicules en raison de l'existence de données urgentes (par exemple, des données d'accident ou d'urgence). Par conséquent, pour respecter un niveau de qualité de service, DOVEQ utilise trois fonctions de qualité de service : classification du trafic, contrôle de surcharge et contrôle d'admission. L'évaluation des performances dans le simulateur de réseau OMNeT++ avec les frameworks Veins et SUMO montre l'efficacité de DOVEQ.

Mots-clefs : Data offloading, Road-side Unit (RSU), Quality of Service (QoS) provisioning, vehicular network; Vehicle-to-Vehicle (V2V) Communication, Vehicle-to-Infrastructure (V2I) Communication.

1 Introduction

In vehicular networks, vehicles carry various types of data, such as accident data of nearby incident, emergency health data of patients and road traffic conditions. Such data needs to be offloaded to RoadSide Units (RSUs) through Vehicle-to-Infrastructure (V2I) communications (i.e., V2I data offloading) when vehicles come into their coverage so that RSUs, which are equipped with edge servers, can analyze and process the data for taking required actions or forward the data to the cloud. Therefore, data offloading is a core component of vehicular networks. The RSUs have been developed for more than ten years, however they are still not widely deployed [HLW20]. Therefore, there is an intermittent connectivity of RSUs and a vehicle cannot always be in RSUs range. Some data carried by vehicles can be very urgent and needs to be offloaded to RSUs as soon as possible, such as accident data of nearby incident and emergency health data. However, with the intermittent connectivity to RSUs, there might be substantial delay in offloading such data. Vehicle-to-Vehicle (V2V) communications (i.e., V2V data offloading) can be used to reduce such offloading delay. For instance, if there is another vehicle with faster speed that is going to meet RSU sooner, it can take over the data and offload it to RSU. There are some Quality of Service (QoS) considerations that are imperative to be provisioned to determine which data to offload first and how to avoid RSUs from getting overloaded for smooth data offloading.

In this paper, we propose DOVEQ, an efficient data offloading scheme for vehicular networks with QoS provisioning. The main objective is to offload vehicles' data to RSUs as soon as possible. DOVEQ models the connectivity for deciding V2I or V2V data offloading, such as the connectivity time of vehicle with RSU, and with neighboring vehicles heading on the same or opposite direction, offloading capacity and expected time to reach RSU. It ensures the QoS by using the functions of traffic classification, overload control and admission control. To the best of our knowledge, there does not exist any data offloading scheme that jointly considers these features in the literature.

2 System Model

We consider a vehicular network, as presented in Fig. 1, having K RSUs and N vehicles such that $K < N$. In the network a vehicle can either have connectivity with an RSU, or with no RSU but with other neighboring vehicles. The considered scenario is a highway with east-bound and west-bound road having multiple lanes on each direction. A vehicle carries various types of data for offloading to RSU either directly (V2I) or through other vehicles (V2V) using Dedicated Short-Range Communication (DSRC) that is based on IEEE 802.11p standard [LZC+19]. The vehicles move at a variable speed. Each vehicle knows its speed and the distance to the last encountered RSU. This information is exchanged with neighboring vehicles through periodic control messages. The connectivity time of vehicles with RSUs varies from lane to lane.

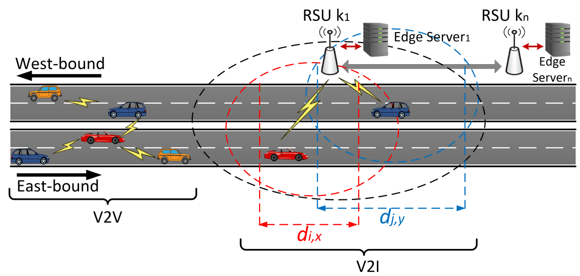


FIGURE 1: System model.

3 Connectivity Modeling

Connectivity Time with RSU The connectivity time estimates how long a vehicle x stays connected to an RSU i and it is used in the calculation of how much data an RSU should grant a vehicle to offload. It is computed by dividing the coverage area $d_{i,x}$ with the speed of the vehicle x.

Connectivity Time with Vehicles Heading on the Same/Opposite Direction This connectivity time estimates how long two vehicles stay connected, they are heading on the same or opposite direction. When two vehicles are moving on the same direction, they stay connected for a longer period of time as compared to vehicle moving in the opposite direction but the gain to offload data to a peer is lower since they are expected to reach an RSU almost at the same time. The connectivity time of two vehicles heading on the same direction is calculated by dividing the least coverage area of a vehicle with the modulus of difference of speeds of both vehicles. The connectivity time of two vehicles heading on the opposite direction is calculated by dividing the least coverage area of a vehicle with the sum of speeds of both vehicles.

In the calculations of all the above three connectivity times, the registration time of requested vehicle with RSUs/vehicles and the waiting time to receive a reply of offloading request need to be subtracted.

Offloading Capacity Offloading capacity is the maximum allowed data size that a vehicle can offload to RSU or other vehicles within the connectivity time. The offloading capacity is directly proportional to the connectivity time. It aims at limiting the size of data offloading and is calculated by taking a product of connectivity time with the data rate of vehicle.

Expected Time To Reach RSU Vehicles exchange the distance to the last spotted RSU with each other. Since we have considered a highway scenario which is a straight road, therefore this information is used by vehicles heading on the opposite direction to estimate the expected time to reach the next RSU (i.e., arrival time to RSU). This is because the last connected RSU for a vehicle will be the next RSU to meet for a vehicle heading on the opposite direction. It is calculated by dividing the distance of last connected RSU of a neighboring vehicle with the speed of vehicle.

4 DOVEQ

4.1 Quality of Service (QoS) Provisioning

QoS is provided using three functions of traffic classification, overload control and admission control.

Traffic classification The data carried by vehicles is classified into three priorities : high (urgent data, e.g., accident data), medium (standard data, e.g., traffic conditions), and low (delay-tolerant data, e.g., backup data). The QoS is provisioned based on the priority and the size of data, i.e., first high, then medium and then low priority data is offloaded. For multiple data with same priority, a greedy approach is used and the data having the largest size that fits the size limitations will be offloaded first.

Overload control The overload control is used in order to avoid overloading the RSUs and keep RSUs' resources available for future vehicles having high priority data. We define an offload criterion by considering threshold values of the maximum allowed load at RSU for medium and low priority data. An RSU allows a vehicle to offload its medium and low priority data if its current load is below the respective threshold values. High priority data has always to be serviced even if other vehicles with medium/low priority data have to be excluded (discussed next). Therefore, there is no threshold for it.

Admission control Admission control in our work operates in two ways. Firstly, an RSU has the authority to stop servicing a vehicle that is currently offloading its low/medium priority data in order to provide service to a vehicle having high priority data. Secondly, in V2V data offloading, a vehicle can only offload its high and medium priority data.

4.2 DOVEQ : Data Offloading for Vehicular Networks with QoS Provisioning

When a vehicle x has direct connectivity with an RSU, it requests V2I data offloading to RSU by informing about its speed, data rate and the sizes of each priority data it wants to offload. If there is no RSU nearby but there are other vehicles, it estimates their expected time to reach their next RSUs and selects vehicle y with the lowest value. x then checks the suitability of y for V2V data offloading using three conditions. Firstly, y should reach the next RSU earlier than itself. Secondly, the difference of the expected time to reach RSU for both vehicles should be significant (i.e., higher than a threshold value). Thirdly, the connectivity time of both vehicles should be sufficient (i.e., higher than a threshold value). After sending V2I/V2V data offloading request, the vehicle waits for a certain time duration to receive a data offloading reply from RSU/vehicle.

When an RSU i receives a data offloading request from x, it calculates the connectivity time with x and its offloading capacity. If x has requested high priority data, RSU checks whether admission control is required. If so, it selects existing offloading vehicle(s) with low/medium priority data and stops servicing them until it is able to accommodate x with high priority data. Finally, based on the offloading capacity, RSU i calculates the amount of offloading data to grant x and sends it an offloading reply.

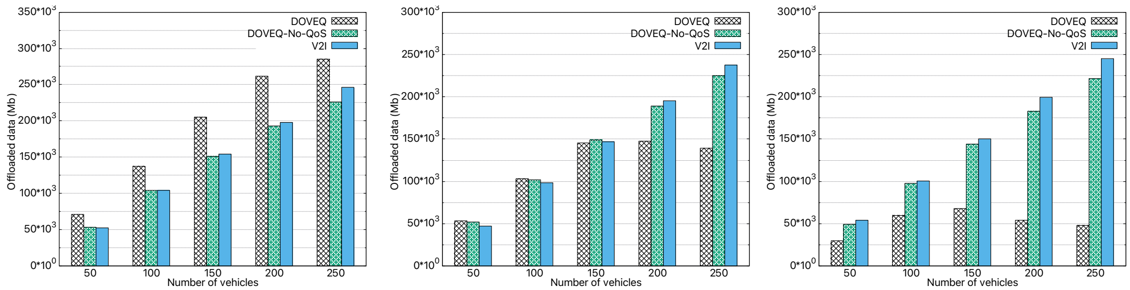
When a vehicle y receives data offloading request from x, it checks its current state. If it is offloading its own data to RSU or another vehicle, it declines the request. If it is receiving data from another vehicle, it performs admission control, if required, otherwise declines the request. Finally, if it is in free state, it estimates the offloading capacity for future RSU and checks its own application data sizes. Based on them, it calculates and sends the maximum high and medium priority data sizes that it can grant to x.

When x receives a data offloading reply from RSU, it simply starts to offload the RSU the amount granted by RSU. Otherwise, if the reply is from vehicle y, x calculates its connectivity time with y based on the heading direction and the offloading capacity to compute the amount of data it can offload and starts the data offloading.

5 Results

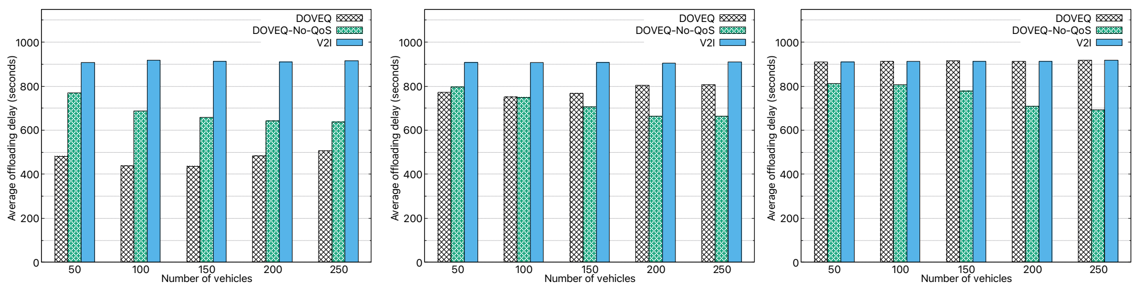
DOVEQ is implemented in network simulator OMNeT++ 5.5.1 with Veins 5.0 and SUMO 1.7.0 frameworks. The considered scenarios are a 30km two-way highway having three lanes on each direction without intersections. Vehicles are equally distributed on each lane and each vehicle departs at a random time and location with a maximum speed of 25m/s. 30 RSUs are uniformly distributed besides the highway with maximum capacity is 10GB. Each vehicle and RSU periodically send beacons with an interval of one second. The total simulation time is 2000 seconds with 20 simulation runs, data rate is 6Mbps, transmission range is 357m and the communication technology is IEEE 802.11p. The performance is compared with a baseline, DOVEQ-No-QoS and a traditional offloading scheme, V2I.

Figures 2 and 3 present the amount of offloaded data and average offloading delay, respectively, of high, medium and low priority data. DOVEQ is able to offload the highest amount of high priority data by achie-



(a) High priority data (b) Medium priority data (c) Low priority data

FIGURE 2: Total offloaded data.



(a) High priority data (b) Medium priority data (c) Low priority data

FIGURE 3: Average offloading delay

ving the lowest offloading delay, thanks to the QoS functions. For medium priority data, all schemes exhibit similar amount of offloaded data and offloading delay. DOVEQ offloads less low priority data than its counterparts because of focusing more on high priority data. DOVEQ-No-QoS is able to achieve slightly lower offloading delay for all high, medium and low priority data because of using V2V offloading.

6 Conclusion

In this paper, we proposed DOVEQ, a data offloading scheme for vehicular networks with QoS provisioning. DOVEQ enabled vehicles to offload their data to RSU through V2I and V2V data offloading. We modeled the connectivity of vehicles with RSU and neighboring vehicles heading on the same/opposite direction, the offloading capacity and the expected time to reach next RSU for vehicles. We used three QoS functions of QoS(traffic classification, overload and admission controls) and presented how a vehicle selects an RSU or neighboring vehicles in DOVEQ to offload data, how the data offloading request is processed at RSU and vehicles and finally, how a requested vehicle processed data offloading reply to start data offloading. The simulation results confirmed that DOVEQ outperformed other schemes by offloading more high priority data by achieving lower offloading delay.

Références

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