THE TIME-BASED K-HOP AWAY V2V ROUTING METHOD FOR MOBILE EDGE COMPUTING (MEC)-BASED VANET DATA OFFLOADING

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INTRODUCTION

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- Since IEEE 802.11p Road Side Units (RSUs) are not deployed everywhere and it needs to pay to use 4G/5G cellular network, the V2I communication that this work assumes is as follows:

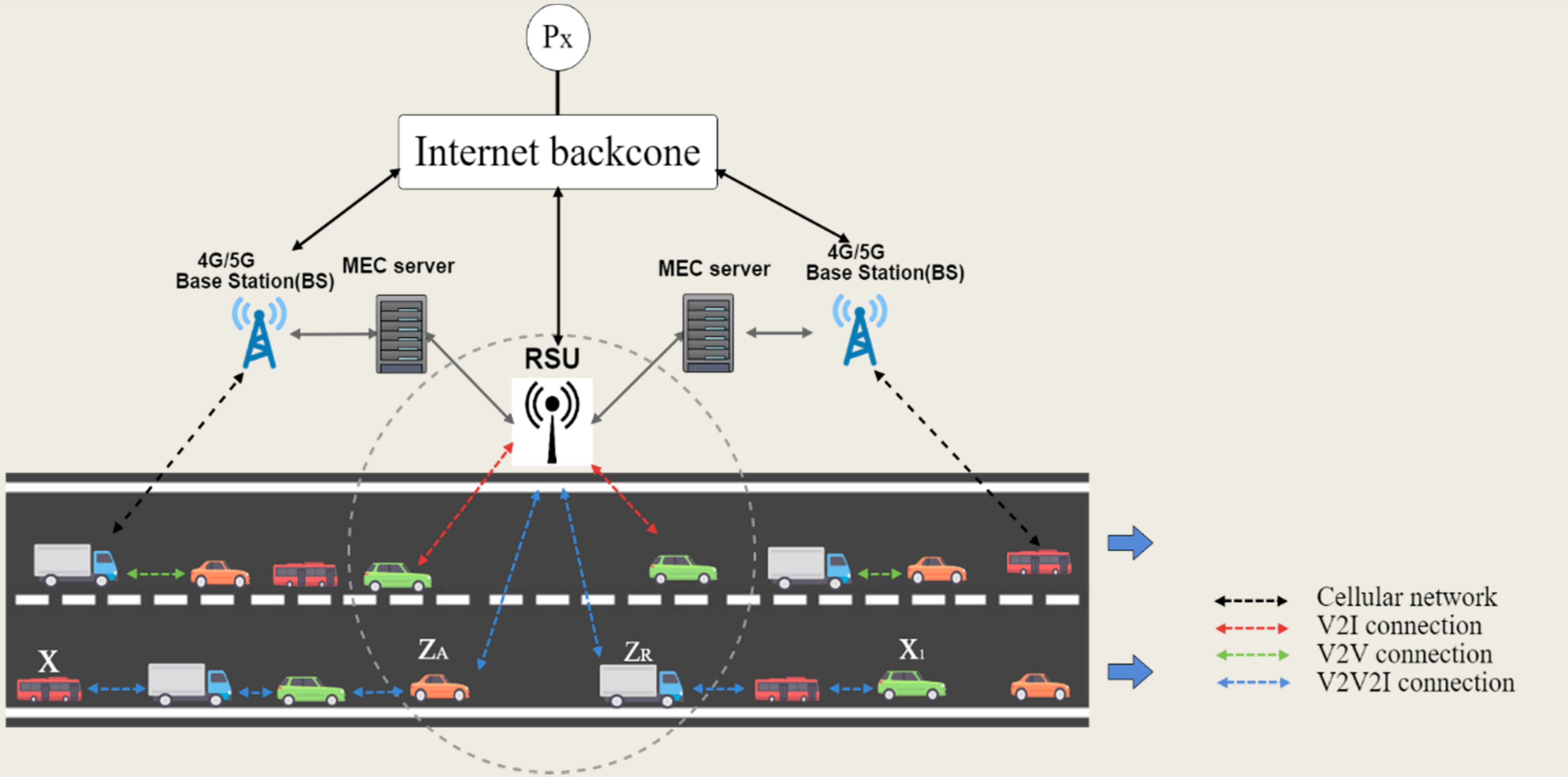
  i) A vehicle X regularly uses 4G/5G cellular network, i.e., through Base Stations (BSs) to communicate with entities in the infrastructure side, i.e., in Internet.

  ii) <u>When vehicle X is inside the signal coverage of an IEEE 802.11p RSU, X switches to use IEEE 802.11p network, i.e., through RSU</u>.

  iii) When vehicle X is outside the signal coverage of the IEEE 802.11p RSU, X switches back to 4G/5G cellular network.

- In this way, <u>**the IEEE 802.11p VANET offloading, which is called V2I VANET offloading hereafter, can be achieved**</u>.

Introduction



Introduction

- To enlarge the offloading effect, the following functional scenarios are considered in this work:
  i) Before vehicle X enters into the signal coverage of its ahead IEEE 802.11p RSU, if there is a k-hop V2V path between X and the signal coverage area of the ahead IEEE 802.11p RSU, i.e., the other end vehicle of the k-hop V2V path is inside the signal coverage of the ahead 802.11p RSU, then X can have the V2I VANET offloading using the k-hop V2V path.
  ii) When vehicle X leaves the signal coverage of the IEEE 802.11p RSU, if there is a k-hop V2V path between X and the signal coverage area of the rear 802.11p RSU, i.e., the other end vehicle of the k-hop V2V path is inside the signal coverage of the rear 802.11p RSU, then X still can maintain the V2I VANET offloading using the k-hop V2V path.
- In this work, the Mobile Edge Computing (MEC)-based 802.11p VANET offloading using the k-hop V2V2I path, on which (i) n includes the hop count of the link between the end vehicle of the V2V path and RSU and (ii) I denotes RSU, is proposed.

Introduction

- In our proposed architecture, each BS is associated with an Mobile Edge Computing (MEC) server;
- An MEC server is in charge of those RSUs that are inside the signal coverage of the corresponding BS.
- Each vehicle is equipped with an On Board Unit (OBU) that has a 4G/5G cellular network’s interface and an IEEE 802.11p network’s interface.
- Each vehicle can (1) use the 4G/5G cellular network’s interface to have V2I communication over the 4G/5G cellular network or (2) use the IEEE 802.11p network’s interface (i) to have V2I communication, which is through RSU or (ii) to have V2V communication, which is through OBU.
- Each vehicle reports its context information (speed, direction, location, neighboring vehicles’ IDs, etc.) to the MEC server using the 4G/5G cellular network, even if it is in the V2I VANET offloading situation.

Main Issues

Main issues that should be tackled in the k-hop V2I VANET offloading for the 4G/5G cellular network are as follows:

1. How to determine the offloading agent (OA)?
2. How to find and construct an offloading path when a vehicle is not in RSU's signal coverage, for which the vehicle is driving toward RSU's signal coverage or away from RSU's signal coverage?
3. When the OA is out of RSU's signal coverage, how to keep this V2V2I offloading path?
4. If the V2V2I offloading path is unexpectedly disconnected temporally, how to repair the offloading path?

THE CONTROL SCHEME

The Control Scheme

The control flow of the proposed MEC-based V2I VANET offloading method is as follows:

- Let vehicle X be the vehicle to make V2I VANET offloading.
- Three phases of the offloading control procedure is as follows:

  (i) The detection and shrinking phase : vehicle X is driving toward the ahead RSU's signal coverage,

  (ii) The staying inside RSU phase : vehicle X is inside RSU's signal coverage

  (iii) The detection and extending phase : vehicle X is driving away the RSU's signal coverage.

The Control Scheme

- Initially, vehicle X is using 4G/5G cellular network to communicate with P_X and all of the vehicles report their contexts to the MEC server periodically.
- When the MEC server finds a suitable V2V2I offloading path for vehicle X, the MEC server sends messages to the constituent vehicles of the V2V2I offloading path to help X forward data.
- All of the constituent vehicles of the V2V2I offloading path report their contexts to the MEC server synchronously, for which the timing can be done through the use of GPS.
- After receiving the contexts of the V2V2I offloading path's constituent vehicles, the MEC server calculates each V2V link time and V2I staying time to update the remaining offloading time of the corresponding V2V2I offloading path.

I. Driving toward the ahead RSU’s Signal Coverage

- When a V2V2I offloading path is used, it needs to keep this offloading path as long as possible until vehicle X is inside RSU’s signal coverage.
- The Detection and Shrinking algorithm (DAS) is proposed to deal with the situation of driving toward the ahead RSU.
- If the offloading agent (OA) is driving away RSU’s signal coverage, a new OA can be found to keep the V2V2I offloading path.
- If a constituent vehicle of the offloading path drives away unexpectedly, it will trigger the Path Recovery algorithm to try to find a neighboring vehicle to repair the V2V2I offloading path.

I. Driving toward the ahead RSU's Signal Coverage

- If it cannot keep the V2V2I offloading path for vehicle X, then the MEC server notifies vehicle X to switch back to the 4G/5G cellular network.
- When vehicle X is inside RSU's signal coverage, the DAS algorithm is ended and the offloading is executed directly by vehicle X itself, i.e., it communicates with RSU directly.

II. Driving inside RSU's Signal Coverage

- Since vehicle X receives RSU's signal directly, the V2V2I offloading path for X is terminated and X communicates with its peer P_X through RSU in Internet.
- In this phase, the MEC server keeps detect and calculate vehicle X's staying time inside RSU's signal coverage.
- If vehicle X's geo location on the next reporting time point is outside RSU's signal coverage, the Detection and Extending algorithm (DAE) is triggered for X to find an offloading path to communicate with its peer P_X through RSU.

III. Driving away the RSU Signal Range

- When vehicle X's geo location on the next reporting time point is outside RSU's signal coverage, the Detection and Extension algorithm (DAE) is executed to find an OA and the corresponding offloading path for vehicle X when X is driving away RSU more and more.
- When the OA is leaving RSU's signal coverage, it needs to try to find the other OA to keep the offloading path.
- If a constituent vehicle of the offloading path drives away unexpectedly, it will trigger the Path Recovery algorithm to try to find a neighboring vehicle to repair the V2V2I offloading path.
- If it cannot keep the V2V2I offloading path for vehicle X, then the MEC server notifies vehicle X to switch back to the cellular network.

IV. Path Recovery

- Let the V2V2I offloading path of vehicle X be composed of vehicle V_i , i = 1..n, for which V_n is the offloading agent.
- When vehicle V_i is changing its speed or direction such that it is driving out of the OBU's signal coverage of V_{i-1} and V_{i+1}, then the path recovery phase is triggered.
- If OA drives away suddenly, OA needs to send a message to the MEC server to find the other OA.

PERFORMANCE ANALYSIS

Simulation environment

- In this work's simulation environment, SUMO and NS-3 simulator were used to simulate the VANET offloading scenario.
- The SUMO provides urban vehicle's mobility with collision avoidance, customized road environments and randomize driving behaviors. The vehicle is driving in 5.0 km × 10 m region with multiple intersections for which SUMO is used to generate more realistic mobility patterns.

Performance matrices

5 scenarios that are compared are as follows:

(1) The traditional offloading scenario for which the offloading source is allowed to have offloading only when it is inside RSU's signal coverage

(2) The offloading scenario of stages 1/2/3: Initial with DAS

(3) The offloading scenario consisting of stages 1/2/3/5: Initial with DAS and Path Recovery

(4) The offloading scenario consisting of stages 1/2/3/4: Initial with DAS and DAE

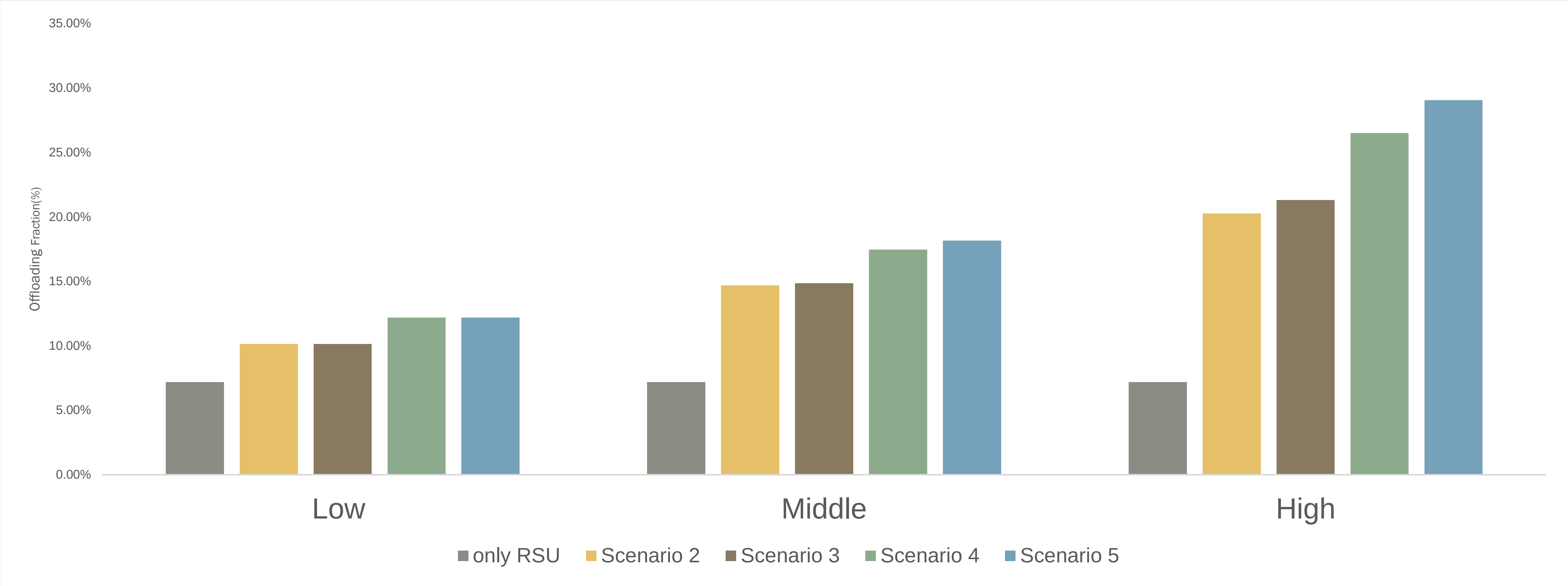
(5) The offloading scenario consisting of stages 1/2/3/4/5: Initial with DAS and DAE and Path Recovery

Each scenario was executed in situations of low/middle/high vehicle density for thirty times. The corresponding result is the average of these thirty times' experiments.

Offloading fraction

- Scenario 1 only has 7.1% of data can be offloaded.
- In the situation of low/middle/high density, the offloading fraction are (10.14%, 10.14%, 12.2%, 12.2%)/(14.69%, 14.86%, 17.46%, 18.16%)/(20.27%, 21.32%, 26.51%, 29.07%) for scenarios 2, 3, 4 and 5 respectively.
- Comparing with the traditional offloading method, i.e., scenario 1, the proposed k-hop offloading method can offload 1.42 to 1.71/2.06 to 2.55/2.85 to 4.09 times of the data in low/middle/high density's situation depending on the adopted method.
- The results show that the higher density it is, the more offloading fraction it has. The reason is that more vehicles can be forwarders and OA when the density is increased and thus the probability of constructing a k-hop offloading path is also increased.

Offloading fractions with different vehicle's density



CONCLUSION

Conclusion

- This work has proposed a time-based k-hop away V2V routing method based on MEC architecture, for which the data offloading can be executed k-hop before or after the corresponding IEEE 802.11p RSU. Using the MEC server, the k-hop V2V offloading path, including the constituent forwarding vehicles and OA, can be derived and monitored.
- Comparing with the traditional offloading method, in which a vehicle is allowed to have data offloading when it is inside the signal coverage area of a RSU, the proposed k-hop away VANET offloading method can have 1.42 to 4.09 times of data offloading depending on the adopted method and the vehicle's density.