# OPUVRE: Overall Performance for Urban Vehicle Routing Environments

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**Abstract.** In recent years, with the great development in assisted driving, traffic monitoring and vehicle entertainment applications, vehicle networking (VANET) attracted a large number of academic research. Because of the vehicle mobility, wireless transmission ranges limit and the loss of wireless channel characteristics in VANET, providing a reliable multi-hop routing protocol in VANET is a significant challenge. This paper proposed a VANET routing protocol OPUVRE (Overall Performance for Urban Vehicular Routing Environments). OPUVRE is an overlay link state routing protocol .It uses traffic density, distribution uniformity and road length to calculate the score of each road, then uses the Dijkstra algorithm to select the best routing path. We evaluate OPUVRE against the traditional geographic routing protocols GSR and LOUVRE. The result shows that OPUVRE provides a higher performance in average packet delivery radio (PDR) and average latency.

**Keywords:** overlay link state routing protocol, traffic density, distribution uniformity, road length.

## 1 Introduction

Intermittent VANET should rely on the effective Ad hoc network routing strategies to ensure the successful transmission. According to AODV (Ad hoc on-demand) [1] distance vector routing protocol, when a mobile node needs to deliver a packet, the continuous connected path will be established on demand. But the constringency period can't meet the VANET requirements because of frequent topology, high mobility and link breakages.

GPSR (Greedy perimeter stateless routing) [2] is the first geographical protocol, it use greedy and perimeter mode together to forward packets. But it often has a bad performance in the intersections. GSR(Geographic Source Routing) [3] protocol, which improved from GPSR, use RLS(Reactive Location Service) to get destination position, and then use electronic map and Dijkstra algorithm to calculate the shortest path to the destination node. The disadvantage is that whether there are sufficient vehicles to support the road connectivity is uncertain. In other words, the shortest path is not the best path. GPCR (Greedy Perimeter Coordinator Routing) protocol [4] improved from GPSR utilizes restricted greedy mode at the intersections of streets. It

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does not depend on any additional equipment, such as electronic maps, location-based services. However its performance depends on correct determination of forwarding direction node at the intersections. In areas of poor connectivity, GPCR protocol has extremely high dependency on intersection node. One advantage of CAR (Connectivity Aware Routing) [5] is that the connected path between source node and destination node could be found when the source node is positioning the location of destination node. The connected path has adaptability, when link breakage appears, it needn't to re-search process. But the routing overhead is still high. LOUVRE (Landmark Overlays for Urban Vehicle Routing Environments) [6] assumes every car is equipped with GPS (Global Positioning System) to get its current location and electric map to get road information and density of vehicles. But its density threshold are always too low because it don't consider the distribution uniformity. GyTAR(Geographic Routing in Urban Vehicular Networks) [7] is an intersection-based geographical routing protocol that is capable of finding robust and optimal routes with urban environments, The main principle behind GyTAR is the dynamic and in-sequence selection of intersections through which data packets are forwarded to the destinations. The intersections are chose considering parameters such as the remaining distance, vehicle density and distribution uniformity. But GyTAR can only guarantee the next street have a good performance. It may be not the best candidate street in routing path from the view as a whole.

## 2 OPUVRE

OPUVRE propose a geo-proactive overlay routing solution that uses traffic density, distribution uniformity and road length as the metric for route creation. We discuss our assumptions and describe our routing protocol in this section.

### 2.1 Definitions and Assumptions

OPUVRE define a junction as one where more than one road segment meets. A road segment is a road which cars are on and is only up to the junction. In other words, the road segment before a junction is different from the road segment after the junction. Finally, a junction node is a node at a junction.

OPUVRE make the following assumptions when designing our routing protocol:

- All nodes constantly know their position and global time thanks to a NAV/GPS system, possibly enhanced with kinematic models when GPS signal is lost. Moreover, the NAV/GPS can provide the road topology information of any node given its location;
- Local time across nodes is synchronized with GPS;
- Location service allows finding the location of a node;

- Non-junction nodes on a road can only transmit to one other and not to other non-junction nodes in adjacent roads unless these non-junction nodes are on road segments that are extensions of each other. This is due to road side obstacles such as buildings and trees;
- Junction nodes, these nodes located at junctions, are the only nodes that can transmit to neighboring nodes on a different road segment since they are the only types of nodes at a junction.

### 2.2 OPUVRE Routing

OPUVRE is an overlay link state routing protocol whose link state table contains information for routing between overlay nodes represented by junctions. We rely on the on-board NAV system to provide the map of the area. This map is used to construct a road topology graph with roads as vertices and edges between the two roads. We creating the overlay link state table, we use the well-known Dijkstra's forward search algorithm to pick the route whose sum of road scores is minimal. The minimal sum gives us the small number of hops and high deliver ratio to the destination.

OPUVRE use the cellular mechanisms similar to GYTAR to collect the information of the road. In addition, we need an information collection unit on each junction. These units have two functions. On the one hand, they collect the road information around the junction and broadcast the existing road information to the nearby vehicles, then the vehicle broadcast these information to other vehicles. On the other hand, they update their road information through interaction with other information collection units. In order to improve the speed of interaction in units, they can use some other special communication mode.

Although each overlay link state routing table entry is a road instead of a node to preserve scalability, the number of roads can increase when the map become too big. We keep the full overlay link states up to a predefined grid area. The boundary points of the grid will keep overlay link states of adjacent grids. To forward to another node B outside of its grid, node A would simply route to the boundary point closest to B and have the boundary point route to B.

To formally estimate the score of an intersection, we define the following notations:

X : the current road;

Score(X) : Score(X) must bigger than 0 or road X will have no connectivity

$\mathrm{N}_{avg}$: average number of vehicles per cell

L : road length

$\mathrm{N}_{ideal}$ : constant that represents the ideal connectivity degree we can have within a cell;

σ : standard deviation of cell density

k : constant that can adjust cell density threshold $\frac{k-1}{k}(1+\sigma)\ \mathrm{N}_{ideal}$
Hence

$$\mathrm{Score(X)} = \frac{\mathrm{L}}{1-\mathrm{kmax}\left(1-\frac{\mathrm{N_{avg}}}{\mathrm{N_{ideal}}}\cdot\frac{1}{1+\sigma}0\right)}\ (\mathrm{Score(X)} > 0) \quad (1)$$

As we can see, this equation is based on two factors:

The shorter the road length X is and the smaller the average number of vehicles per cell $\mathrm{N}_{avg}$ is, the lower the Score(X) is. So the low Score(X) (S>0) represents that road X is a good candidate road. Hence, it ensures that we can use Dijkstra's algorithm to select the best routing path.

If $\mathrm{N}_{avg}$ is lower than the cell density threshold $\frac{k-1}{k}(1+\sigma)\mathrm{N}_{ideal}$, Score(X) is lower than zero, it represents that road X have no connectivity and X can't be a candidate road in any case. If $\mathrm{N}_{avg}$is bigger than $(1+\sigma)\mathrm{N}_{ideal}$, Score(X) is equals to L. it represents that road X have a well connectivity and road X can be a perfect candidate road.

We distinguish between two types of routing in OPUVRE: inter-road routing or overlay routing, and intra-road routing or underlay routing. Inter-road routing is used to route packets between roads on the overlay network, and intra-road routing is used to forward packets between vehicles within a road on the underlay network. Both inter-road and intra-road routing require consulting the overlay link state table to determine to which road to forward next. Inter-road routing uses this information to correctly locate a forwarding neighbor on the new road. Intra-road routing uses the next road information from the overlay network to determine the best intersection to forward packets to. Then, it would choose the neighbor that makes the furthest progress to the intersection on the underlay network.

Packets are always routed by using inter-road routing, the overlay network providing routing directions, while the underlay network providing a guaranteed greedy forwarding. Unless a node cannot find any neighbors that are on the next forwarding road, it switches to intra-road routing in order to find a neighbor closer to the intersection where it might have nodes that have neighbors on the next forwarding road. Neighbor discovery is done with periodic beacons.

### 2.3 Recovery Strategy

Despite the road we choose have well connectivity, it can't guarantee that every vehicle always have a next hop node and encounter a local maximum. Then, depending on the application requirements, two recovery strategies have been designed. If applications are time-sensitive, packets can be routed back to the previous road where the second best road (the sum of road scores is second minimal) to the destination can be chosen. Packets are only dropped if an alternative road is not alternative road is not available. If the application are delay-tolerant, packets can be stored, carried, and the forwarded until the node meets another vehicle on the next road in the routing table.

# 3 Performance Evaluation

In this section, we evaluate the performance of OPUVRE. Experiment in this paper consists of two parts: In the first part of the experiment, we optimize our routing scheme by comparing its performance with different constant k. In the second part of the experiment, we evaluate our routing scheme by comparing its performance with GSR and LOUVRE, two well-known geographic routing protocols that have been previously applied in VANET environments. In particular, we are interested in two types of metrics: 1) packet delivery ratio (PDR), 2) average latency.

The open source tool NS2 (Network Simulator 2) [8] is used to simulate the wireless data transmission. The OPUVRE is implemented in NS2, and the programming language used is C++ and Tcl/OTcl. The key simulation parameters are summarized in Table 1:

**Table 1.** Simulation Parameters

| | |
|---|---|
| Simulation time | 300 sec. |
| Topology Size | 3000mX3000m |
| Mobility Model | VanetMobisim[9] |
| Number of intersections | 11 |
| Number of roads | 31 |
| Number of Vehicles | 250~500 |
| Average vehicles velocity | 50km/h |
| Source/destination | Random（50 connections） |
| Propagation model | Two-ray ground |
| Media Access Control | 802.11b |
| Transmission range | 250m |
| Data packet type | CBR(Constant Bit Rate) |
| Data pack size | 512 B |
| Packet sending rate | 0.1~1sec |

Due to static obstacles (such as building), we assumed that nodes on different roads cannot communicate to one another, unless two roads share the same extension in either the horizontal or vertical direction.

## 3.1 Fine-Tuning Constant K in OPUVRE

Constant K can adjust cell density threshold $\frac{k-1}{k}(1+\sigma)\mathrm{N}_{ideal}$. When k is small, the road of low road density of vehicles will be taken into account as a candidate routing road. We define the lowest continuous connectivity probability that can be accepted is 80%. Previous studies have shown that the continuous connectivity probability under conditions (1.5km, 6/cell), (1.5km, 8/cell) (2.75km， 8/cell) and (4km, 8/cell) are 77.5%, 91.2%,83.2% and 75.6%. So the average number of vehicles per cell should be bigger than 8. Hypothesis $\frac{k-1}{k}(1+\sigma)\mathrm{N}_{ideal}=8, \sigma=0, \mathrm{N}_{ideal}=14$, we can calculate K=2.33.

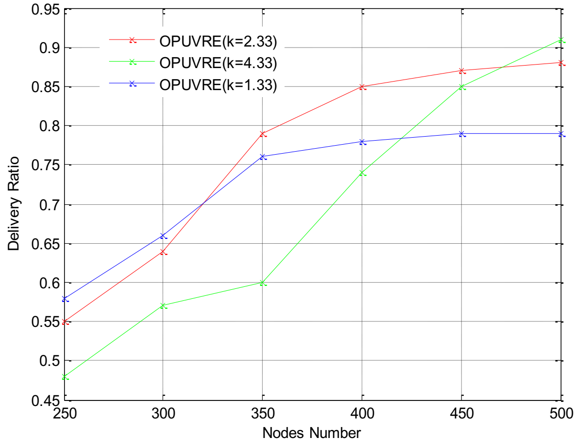


**Fig. 1.** Sending Rates=0.5

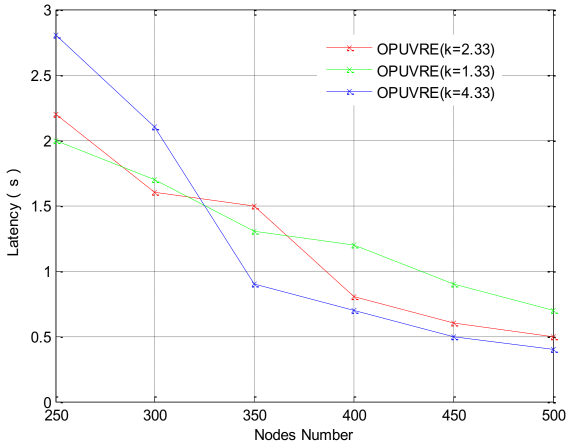


**Fig. 2.** Sending Rates=0.5

To study the effect of K in routing performance, we simulated OPUVRE in three cases: k = 1.33, k = 2.33, k = 4.33. The results in Figure 1 and Figure2 showed that when the node number is small, k =1.33 can get the best performance in PDR and average latency. When the node number is big, k=4.33 can get the best performance. The reason may be that the smaller K is, the smaller cell density threshold $\frac{k-1}{k}(1+\sigma)\mathrm{N}_{ideal}$ is. When the node density is low, the small threshold can ensure there are enough candidate roads and select a relatively well routing path. When the node density is high, there are enough candidate roads which have good connectivity, In this case, the big K can ensure that the roads in routing path all have good connectivity because of the big cell density threshold $\frac{k-1}{k}(1+\sigma)\mathrm{N}_{ideal}$. In order to obtain a stable performance in OPUVRE, we set k=2.33.

### 3.2 Compare with GSR and LOUVRE

**Packet Sending Radio(PDR)**

Figure 3 and Figure 4 show the performance of the average PDR in OPUVRE are better than the others. This is mainly because that all the calculate roads in OPUVRE have a high continuous connectivity probability because of the high vehicle density and high uniformity. On the other hand, some calculate roads in GSR have a low continuous connectivity probability because of the high vehicle density. It leads to a frequent interruption in forwarding packets. Although LOUVRE considering the effect of road vehicle density on connectivity, it don't consider the effect of road vehicle distribute or distinguish between the roads of which vehicles density are higher than threshold.

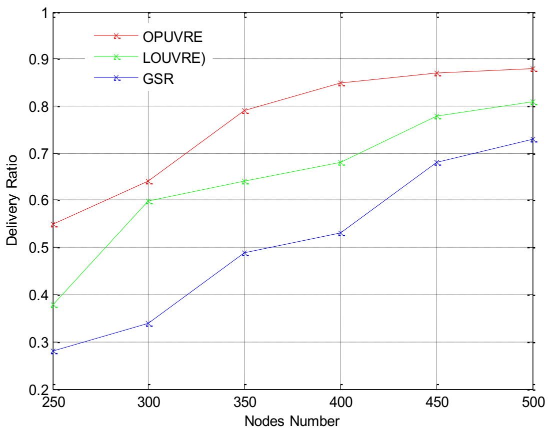


**Fig. 3.** Sending Rates=0.5

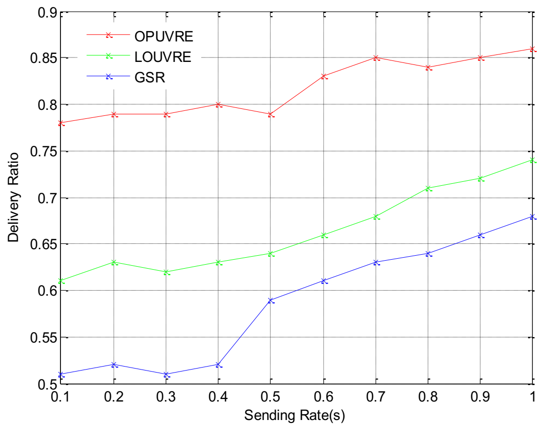


**Fig. 4.** Nodes Number=400

At the same time, we noted that PDR performance in OPUVRE is better than GSR and LOUVRE, but the difference in low density are more obvious. OPUVRE are higher than GSR by 27% and higher than LOUVRE by 18%.When the node number increased to 500,OPUVRE are only higher than GSR by 15% and higher than LOUVRE by 7%.

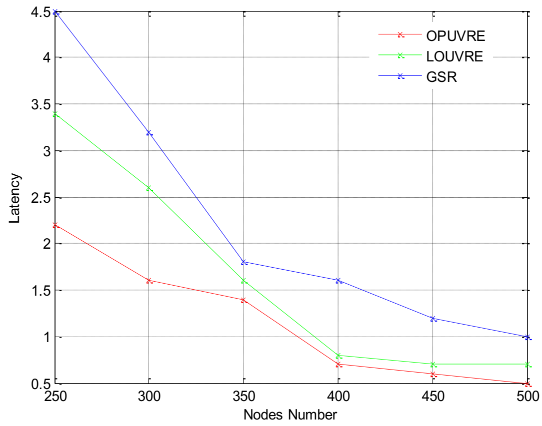


**Fig. 5.** Sending Rates=0.5

**Average Latency**

Figure 5 show the performance of the average latency in OPUVRE are better than the others. This is mainly because the candidate roads in OPUVRE have a high vehicle density, so there are more candidate vehicles in forwarding packets in road

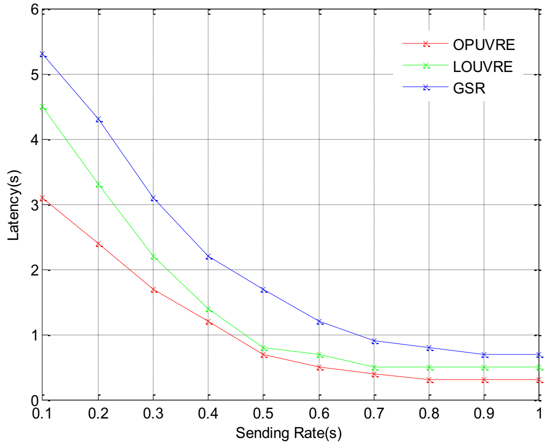


**Fig. 6.** Nodes Number=400

and more likely to choose a next vehicle which is nearer to the destination, then the average hop count become less. At last, the average latency become less because of the less hop count.

# 4 Conclusion

This paper presented OPUVRE, a density and uniformity based landmark overlay routing protocol for urban vehicular environments. We described the concept and the protocol as well as a novel road score estimation scheme. We implemented the protocol in NS2 and find the suitable k in OPUVRE, then compare it with GSR and LOUVRE protocols using realistic road information. Results showed that due to the smart calculate of road score, OPUVRE provide a better pack delivery ratio and latency than the other protocols. Future work includes verifying the necessity of recovery mode and how to reduce the communication overhead in traffic information interaction.

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