# Utilizing One-way Roads in Static-node-assisted Vehicular Networks

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***Abstract*—As motor vehicles have been populated all over the world, studies on VANETs, which is the autonomously structured networks with vehicles, are increasing. Although geographic routing approaches are usually used in VANET, it hardly works at night since it requires relatively high vehicle density. To improve the communication performance and reliability even when vehicle density is low, several static-node-assisted routing schemes that suppose wireless nodes placed at each intersections. This approach significantly improve the reliability of vehicular networks. However, since those static-node-assisted networks suppose bi-directional links in which cars that carry packets run bi-directionally, they cannot utilize one-way roads in their routing paths. To solve the problem, we propose a method to forward necessary control packets using a detour path instead of reverse forwarding in one-way roads. We conduct a simulation of the proposed method to clarify the effect of the proposed method to utilize one-way roads.**

## I. Introduction

As motor vehicles have been populated all over the world, many studies to utilize vehicles as a communication devices that benefit people and the human societies. In vehicular networks, traditionally, many studies utilize geographic routing such as GPSR [1] and [2] in which vehicles opportunistically communicate with each other to send packets to their destinations. However, to achieve reliable communications, geographical routing requires high vehicle density, but in reality such special situation exists only in a metropolitan area in a busy time period.

To enhance the reliability even in a sparse scenarios, a technique of static-node-assisted routing protocol that utilize static nodes placed at each intersections [4] [5] [6]. By temporarily store packets at static nodes and send packets only when the vehicular that will approach destination, packet delivery ratio dramatically improves. However, since, in those schemes, require control messages exchanged between neighbor static nodes bi-directionally, it is one of the problems that one-way roads are not possible to use. This would be one of the room to improve those schemes.

In this paper, we propose a method to use one-way roads as a packet delivery paths to improve the performance of static-node-assisted routing protocols for vehicular networks.

## II. Proposed Method

We propose a method to utilize one-way roads by way of detour forwarding instead of reverse forwarding on the one-way road. To utilize a road between two intersections as a forwarding link of packets, static-node-assisted routing protocol in general has to exchange control messages between the two static nodes at the intersections.

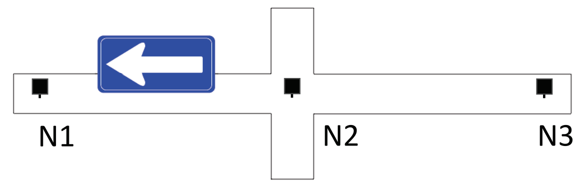


Fig. 1. Example of One-way Roads

We suppose a one-way road, and let $N_2$ be the starting node and $N_1$ be the terminating node. (Example of one-way roads are shown in Fig. 1. We assume that $N_1$ and $N_2$ are adjacent with each other, and $N_1$ is aware of the link to reach $N_2$. In this case, $N_1$ can revive a control message from $N_2$, but $N_2$ is not possible to do it. So, our task to utilize the one-way link $N_2 \rightarrow N_1$ is to enable $N_2$ to receive the necessary control message from $N_1$.

The proposed step to do this is in the following:

(1) $N_1$ recognizes that the $N_2$ is the starting node of the one-way road. The condition of this is to suffice both of the following conditions.
  a. $N_1$ receives a message from $N_2$.
  b. $N_2$ is a neighbor.
  c. The message from $N_2$ does not include any information that reflect on the information $N_1$ has sent before.

(2) $N_1$ find the routing entry to $N_2$, which is computed by the deploying routing protocol if a path with bi-directional links exists from $N_1$ to $N_2$.

(3) $N_1$ sends the necessary control packets via packet encapsulation using a tunnel to $N_2$.

The above mechanism enables us to deliver required control messages reversely to the starting node of one-way roads, which enables routing protocols to utilize the link as the forwarding paths.

## III. Evaluation

We evaluated the proposed method using a simulator that we developed with C++ language, which simulate only the network layer and does not simulate PHY and MAC layers. The road map we used is shown in Fig. 2 where static nodes are placed at several intersections. For mobility model, we use SUMO [7]. We generated car traffic patterns according to the parameters shown in Fig. 3 using SUMO, and measured the average delivery delay under variation of the number of cars generated in a unit time. Other parameters related with the simulation is also shown in Fig. 3.

Fig. 4 shows the result obtained from the simulation. From the result, the proposed method reduced the delivery delay by using one-way roads. In this scenario, utilizing one-way road was effective.

## IV. Conclusion

In this paper, we propose a method to utilize one-way roads in a static-node-assisted routing protocols in vehicular networks. Although static-node-assisted routing protocols have a significant effect on the performance, one-way road is not utilized by them since bi-directional massage exchange is required. This problem would have a significant performance degradation in several cities such as Kyoto, where lots of one-way roads exist in a grid shape map. Through the simulation, we showed that utilizing one-way road is possibly effective by using a scenario where map has many one-way roads like Kyoto city.

## References


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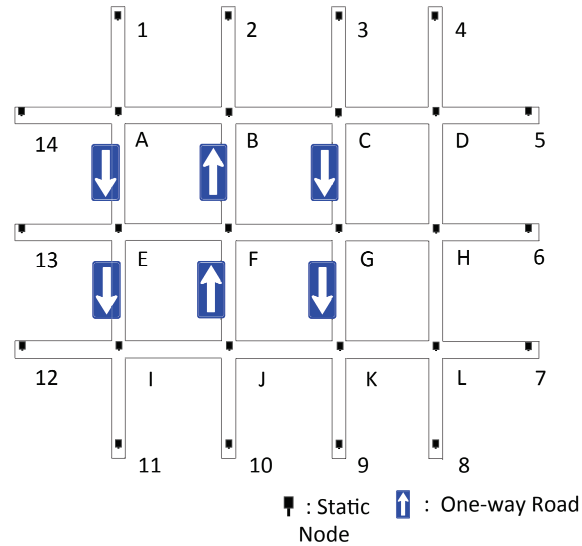


Fig. 2. Map Used in Simulation

| | |
|---|---|
| Node Interval (Distance) | 300m |
| Traffic Signals | N/A |
| Number of Lanes | 3 |
| Special Lane to Turn Left/Right | N/A |
| Car Maximum Speed | 50km/h |
| Car Moving Patterns (Normal Intersection) | Straight: 90%, Turning Right/Left: 5% |
| Car Moving Patterns (T-type Intersection) | Straight: 95%, Turning Right/Left: 5% |
| Car Moving Patterns (T-type Intersection 2) | Turning Right/Left: 50% |
| Car Generation Place | At the End of streets 1~14 |
| Car Generation Rate (per minute) | 9, 14, 19, 23, 28, 34, 42, 47 |
| Source Nodes of Packets | A,B,C |
| Destination Nodes of Packets | I,J,K |
| Packet Generating Time | 600 – 3000 sec. |
| Number of Packets Generated | 500 |
| Simulation Time | 3600 sec. |
| Maximum Load of Each Car | 50 Packets |
| Maximum Load of Each Static Node | 100 Packets |

Fig. 3. Simulation Parameters

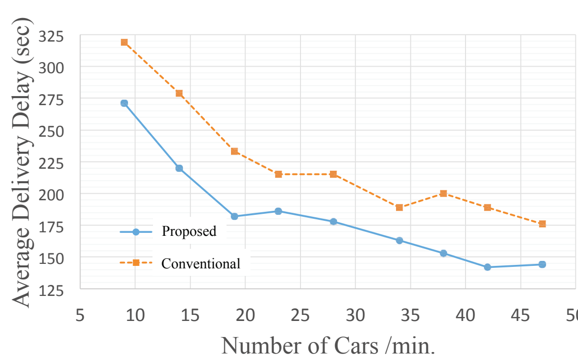


Fig. 4. Average Delivery Delay