A V2V intersection control without traffic lights

*An experiment report

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***Abstract*—Assuming there are no traffic signals at a road intersection, we use V2V communication to direct the flow of vehicles through the intersection. And we design a control strategy and experiment simulation to observe the effects of the V2V communication strategy on SUMO and OMNet. According to the control strategy, the right-side car has a higher priority to pass the intersection first.**

***Index Terms*—non-traffic light, intersection, V2V, communication, control**

I. Introduction

In urban traffic, traffic lights play a significant role. When traffic lights are used at intersections with heavy traffic, vehicle efficiency can be efficiently increased, and participants' safety can be safeguarded. However, using traffic lights at crossroads with less traffic, such as suburbs and urban non-main roads, might waste resources and decrease the efficiency of vehicle traffic under specific circumstances. They are inefficient in some situations and require money to maintain [1]. In actual life, there are also road intersections without traffic lights and it is expensive to install traffic lights at every intersection. In these situations, the guarantee of the safety of pedestrians rely on the active detection of the driver alone.

Because it does not require total vehicle stopping at the intersection as is required by a standard traffic signal, intersection diving control via V2V communication will help reduce waiting and trip delays from the perspective of traffic efficiency.

II. Experiment

To assess the impacts of V2V communication regulation, we used the Normal Traffic Light System (TLS) as the control group in the experiment. Additionally, 5 distinct vehicle density scenarios were used to track the effectiveness of the V2V communication. The SUMO file depicts the SUMO system, which consists of 4 roads with a total of 8 lanes and is defined in the v2v.rou.xml file. Each road is 1500 meters long, for a total of 6000 meters. The number of cars in the respective experimental group are 300, 600, 900, 1200, and 1500, with the traffic density adjusted to [0.05, 0.25].

The DSRC protocol stack and IEEE802.11p on the physical layer form the basis of the network model. The primary algorithm is on the IEEE 1609.4 application layer. WAVE short message (WSM) is the application layer utilized by the algorithm in wireless access in a vehicle setting (WAVE).

A. Scene building for Simulation

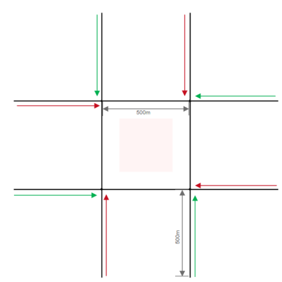

Fig. 1. Vehicle Experiment Network

- The experiment network is a 4-intersection network as shown in Figure. 1.
- Each road is a 500 meters long two-way single lane.
- Each route goes straight without turning.
- There are evenly continuous traffic flow on each route.
- V2V communication area radius is 50 meters.

B. Control group setting

- V2V communication control simulation.
- Nomal traffic light system(TLS) control under the default setting in sumo.
- Set 5 Vehicle density: 0.05, 0.10, 0.15, 0.20, 0.25.(0.05 i.e. A 6000 meters route with 300 vehicles.)

C. Control Strategy

- Right-side vehicles have a greater priority for passing.
- Only when a collision is anticipated do cars slow down.
- When a collision is anticipated, cars will slow down rather than come to a complete stop.
- When the respective vehicles that were due to meet each other at the intersection had left, the speed of the moving vehicles recover to original.

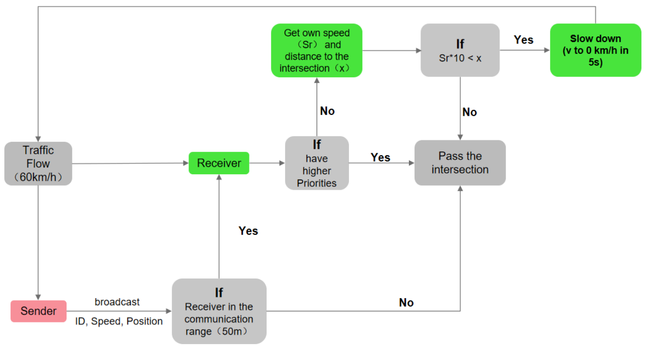

Fig. 2. Vehicle Control Strategy Diagram

III. Algorithm Implementation

- Set up each OBU for each vehicle in OMNeT, and change each OBU's application layer to follow the PSEmergency.cc programming application layer protocol.
- Specify the order of travel (on duty), stating that the right lane will be used first and that traffic at intersections will slow down to make way for the right-most traffic with the highest priority. Only the on-duty car will deliver the emergency message (WSM) at the same time at the application layer, and the other vehicles will only receive the message (receiver).

```
[Config AppOn]
*.node[*1].appl.onDuty = true
*.node[*3].appl.onDuty = true
*.node[*5].appl.onDuty = true
*.node[*7].appl.onDuty = true
*.node[*9].appl.onDuty = true
```

- The creation of WSM messages (more information is available in the handlepositionupdate function). The message includes the sender's current location (represented by XY coordinates), the current road and lane index, and the current vehicle speed. When a sender is in control of a channel, they broadcast.

```
void PSEmergency::handlePositionUpdate
(cObject* obj) {
BaseWaveApplLayer::handlePositionUpdate(obj);
if (onDuty){
    findHost()->getDisplayString();
WaveShortMessage* wsm = new WaveShortMessage();
    populateWSM(wsm);
    wsm->setWsmData();
    if (dataOnSch) {
        startService(Channels::SCH2);
        scheduleAt(SendTime,wsm);
    }
    else {
        sendDown(wsm);
    }
}}
```

- The application layer of the receiver will call the onWSM function to retrieve the message content delivered by the sender as soon as it receives the message. The receiver checks to see if the road and lane it is in match those of the sender. If they are, it indicates that the sender and receiver are in the same lane (i.e., how the front and rear vehicles are positioned), and the recipient is in a situation where no strategy is required. The receiver will encounter the sender at the intersection if they are not in the same lane. It is now required to determine the safe distance and apply deceleration techniques.

```
void PSEmergency::onWSM
(WaveShortMessage* wsm) {
findHost()->getDisplayString();
if (onDuty == false){
    if (onRoute(wsm->getWsmData())) {
    }
    else{
        slowdown();
    }}}
```

- The receiver slowdown function is the next. Here, the traci function is utilized. Get the distance between the receiver and the closest intersection using getlength, then compare it to the predetermined safe distance. Based on the receiver's current speed (getspeed) multiplied by the designated safety time of 10s, the safety distance is calculated. A collision is deemed likely if there is less than the safe distance between the receiver and the closest intersection. At this point, the receiver vehicle is slowed down using the slowdown(0,5) function. Slowdown(0,5) denotes a 5 second deceleration to 0 for the vehicle. Instead of immediately putting a value on the car's speed, this setting is more in keeping with reality.

IV. Result Analysis

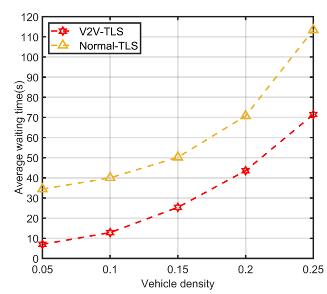

Fig. 3. Average waiting time/Traffic Density

Figure 3 shows that, in the situation of arbitrary vehicle density, the suggested V2V-TLS algorithm is significantly larger than the conventional traffic light method (Normal-TLS). Particularly, the average waiting time of V2V-TLS is 49.48 percent less than that of Normal-TLS when the vehicle density is 0.15, and it is 58.83 percent less than that of Normal-TLS when the vehicle density is 0.25. This demonstrates that V2V-TLS is more appropriate for environments with high vehicle densities because the performance gap between it and Normal-TLS widens as vehicle density rises.

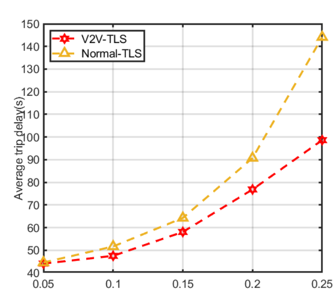

Fig. 4. Average Trip Delay/Traffic Density

According to Figure 4, the average vehicle delay is the average time it takes for each vehicle to go from the departure point to the terminal, and it represents how congested the roads are generally. The figure shows that at all vehicle densities, the average vehicle delay of our suggested V2V-TLS algorithm is less than that of the conventional traffic light Normal-TLS. In particular, the average waiting time for V2V-TLS is 8.01 percent less than it is for Normal-TLS when the vehicle density is 0.1, and it is 15.29 percent less than it is for Normal-TLS when the vehicle density is 0.2. This demonstrates that typical traffic will result in significant delays as the number of vehicles increases.

TABLE I
SIMULATION PARAMETER

Parameter	Value	Unit
Simulation duration	600	second
Scenario	4 intersection	N/A
Total length of the road segment	6000	meter
Vehicular density	0.05, 0.10, 0.15, 0.20, 0.25	Vehicle/meter
Vehicular network protocol stack	DSRC	N/A
Transmission bandwidth	10	MHz
Physical layer	IEEE 802.11p	N/A
Modulation	QPSK	N/A
Data rate	3	Mbps
Vehicle speed	Limit speed 60 km/h and decided by the Krauss car-following model	N/A
Mobility model	Arbitary starting points of the road	N/A
Car-following model	Krauss	N/A
Communication range R0 for on-board unit(OBU)	50	meter
Signal fading model	Nakagami model	N/A
Application layer	WAVE	N/A
Message type	WSM	N/A

TABLE II
EXPERIMENT DATA RESULT

Experiment Group	Traffic Density	Average Waiting Times	Average Trip Delays
V2V-TLS	0.05	7.00	44.10
V2V-TLS	0.10	12.83	47.52
V2V-TLS	0.15	25.36	58.07
V2V-TLS	0.20	43.57	76.84
V2V-TLS	0.25	71.44	98.62
Normal-TLS	0.05	34.41	44.58
Normal-TLS	0.10	40.02	51.66
Normal-TLS	0.15	50.20	64.26
Normal-TLS	0.20	70.74	90.71
Normal-TLS	0.25	113.47	144.10

V. CONCLUSION

The average waiting time and vehicle delay of vehicles have been greatly decreased under the V2V condition and our optimal circumstance settings compared to our conventional traffic lights control group, it can be concluded. Additionally, the V2V can adapt to conditions with a larger vehicle density under our experiment environment setting condition. The remark, however, is not likely to hold true in other circumstances. This experiment solely takes into account the best-case scenario of two-way, vehicle-only traffic with no bicycles or pedestrians. The experimental data performance is anticipated to decline when traffic participants are taken into account. And the control logic is straightforward: performance is anticipated to increase if we incorporate more control priority algorithms and logic into the approach.

REFERENCES

[1] Saini, Sanjay, et al. "An efficient vision-based traffic light detection and state recognition for autonomous vehicles." 2017 IEEE Intelligent Vehicles Symposium (IV). IEEE, 2017.

[2] Songyoung Park(2022). Citing open source for presentations[PowerPoint slides]."Vehicle-2-X: Communication and Control SS22"