Evaluation of Actuated Right Turn Signal Control Using the ITS Radio Communication System

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Abstract
We have been developing the DSSS (Driving Safety Support Systems) by way of ITS radio with 700MHz band, which are used in I2V, V2V, and I2I communication. Additionally, we are recently trying to apply this ITS radio communication system for signal control to reduce traffic congestion. First applying it for such environmental use, we simulated the effect of the actuated right turn signal control in several cases of the accuracy of data, and the ratio of OBU (on-board unit) vehicles. The results of the simulation showed that even if vehicles are positioned accurately within 30 meters of normal distribution, we achieved good effectiveness by actuated right-turn signal control using the DSSS, the same as lower rate OBU vehicles in the conditions of high demand of right turn.

KEYWORDS:
700MHz ITS radio communication system, Actuated signal control, Simulation Evaluation

Background
In Japan we have been developing the DSSS using ITS radio communication system, and examining these test systems in several places. The DSSS promotes safety services, such as like right turn collision avoidance, left turn bike accident avoidance, pedestrian crossings and so on (there is left side traffic in Japan). We have applied 700MHz ITS radio communication systems for the DSSS, providing drivers with information measured by roadside sensors. Vehicles which load OBU for the DSSS also transmit to surrounding vehicles their own data including their positions, speeds, and other vehicle status data for V2V cooperation, such as safety lane changes, collision avoidance at no signalized intersections, etc. Thus the DSSS has been being originally developed to reduce traffic accidents. Now we will try to apply ITS radio communication systems not only for safety use but also for traffic controllers. Roadside units can also receive the data of V2V communications at the same time. It means that infrastructure can get the real time floating car data (RT FCD). We started developing the signal control systems using the FCD via IR beacon before we started developing ITS radio
communication systems. Making use of those experiences, we also have developed this signal control systems. In this paper, we will report on the simulation results of the effectiveness of actuated right turn signal controls using RT FCD as one of the best optimal applications.

**About RT FCD**

*Transmitted Vehicle Data*

Figure 1 shows one image of data sets transmitted from OBU vehicles. The data is transmitted each 100msec. It contains primary data, such as vehicle ID, vehicle position, speed, and GPS time, and option data such as, direction, acceleration, break operations, windshield wipers and indicators (for example, blinker, hazard, etc.).

<table>
<thead>
<tr>
<th>Vehicle ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Position (Lat. Long. Alt.)</td>
</tr>
<tr>
<td>Vehicle Speed</td>
</tr>
<tr>
<td>Timestamp (GPS)</td>
</tr>
<tr>
<td>Vehicle Direction</td>
</tr>
<tr>
<td>Vehicle Acceleration</td>
</tr>
<tr>
<td>Other Vehicle Sensing</td>
</tr>
<tr>
<td>Driver Operation (Stat. of Windshield Wipers, Break, Lights, Blinkers, Hazards, etc.)</td>
</tr>
</tbody>
</table>

Figure 1 Image of Transmitted Vehicle Data

*Assumption of Applying for RT FCD*

Table 1 shows characteristics of RT FCD. We confirm that RSUs with 700MHz band ITS radio communication can catch data transmitted from vehicles as far away as 200~400 meters, in real time. This means that RT FCD is adapted for signal control, especially actuated signal control.

<table>
<thead>
<tr>
<th>Collection media</th>
<th>characteristic</th>
<th>to apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITS radio</td>
<td>+Able to collect in real time</td>
<td>+Actuated Signal Control (instead of vehicle detectors)</td>
</tr>
<tr>
<td></td>
<td>+About 200~400m road range</td>
<td>+Monitor traffic conditions of flow in road of the intersection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+Measure to calculate the signal parameters</td>
</tr>
</tbody>
</table>

So we assume that each type of FCD, (in Japan, there are three types of FCD including RT FCD using ITS radio communication, FCD via IR beacon which is spot communication collecting trajectory data in semi-real time, and FCD via mobile phone which can collect the
vehicle data anytime anywhere except variety delay time), has a different role in traffic management.

**System Overview of Actuated Right Turn Signal Control**

*System Image*

Figure 2 shows the right-turn signal control system applied ITS radio communication system. It consists of signal controllers and wireless communication devices (both roadside and in-vehicle). There are no detectors for right turn vehicles detection. The signal controller decides phase time for right turn only through data from OBU vehicles.

![Figure 2 System Configuration](image)

*Process Flow*

1. Monitor the Vehicle Data
2. Check the Vehicle Data (position, speed, indicator, etc.)
3. Refer to Signal Status & Parameters
4. Estimate Vehicle Behaviors
5. Judge the Existence of Right Turn Vehicles
6. Decide to Prolong Right Turn Signal Time

Figure 3 Process Flow in Actuated Right-turn Signal

Applied for ITS radio communication systems
Figure 3 shows the process flow when signal controller decides to extend the phase of right turn signal in this system. This system has to detect the existence of right-turn vehicles by RT FCD as vehicle position, speed, indicators, and signal status.

**Simulation**

*Actuated Right-Turn Signal Control in Simulator Settings*

We simulated an intersection that is being applied to DSSS in the field of Tokyo, with VISSIM (ver.5.30-09). We took out the values of the data of OBU vehicles from the external program using the command of VISSIM-COM during simulation. After having judged the signal control program on the simulation, having the data set of OBU vehicles in 45 meters right turn lane only on road-2, it prolonged the right turn signal time automatically. Cycle length is 120 seconds with a minimum length of right turn time being 7 seconds, and the maximum length of right turn time is 12 seconds.

![Simulated Intersection](image)

**Traffic Conditions**

We generated vehicle as shown in Table 2 and right turn vehicles only on the road-2 to get a clear evaluation, and we generated the right-turn vehicles at 10~20 percent of ones which passed through the road-2. They sometimes make right-turn queue overflows from a right-turn lane, and also got congested on road-2.
Table 2 Generated Vehicles ([vehicles/hour/road])

<table>
<thead>
<tr>
<th></th>
<th>0 ~ 60 sec</th>
<th>6000 ~ 4200 sec</th>
<th>4200 ~ 4500 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>road-1</td>
<td>400</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>road-2</td>
<td>1200</td>
<td>1200</td>
<td>0</td>
</tr>
<tr>
<td>road-3</td>
<td>400</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>road-4</td>
<td>1200</td>
<td>1200</td>
<td>0</td>
</tr>
</tbody>
</table>

**Evaluation Conditions**

We assume that OBU vehicles compose 10 percent of traffic flow at the maximum because even the up-linked-vehicles with infrared beacons are recently 10 percent of traffic flow in Tokyo. We then simulated OBU vehicles cases at the following values: 1, 2, 3, 5, and 10 percent (of traffic flow). We also evaluated the influence of the accuracy of vehicle position. The value of accuracy which is generated under normal distribution randomly is added to vehicle position in direction of movement. Table 3 shows the accuracy conditions. The maximum difference in value of 30 meters is based on the report of the accuracy of GPS in the valley between tall buildings.

<table>
<thead>
<tr>
<th>Accuracy model</th>
<th>Accuracy conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy model 0</td>
<td>No difference (correct position)</td>
</tr>
<tr>
<td>Accuracy model 1</td>
<td>$2\sigma = \pm 10\text{m}$, maximum 20m</td>
</tr>
<tr>
<td>Accuracy model 2</td>
<td>$2\sigma = \pm 20\text{m}$, maximum 30m</td>
</tr>
<tr>
<td>Accuracy model 3</td>
<td>$2\sigma = \pm 30\text{m}$, maximum 40m</td>
</tr>
</tbody>
</table>

**Evaluation & Results**

We simulated actuated right turn signal control with the ITS radio communication systems in each condition of the accuracy models, which were added to vehicle position and we measured as a total of the delay time of the whole intersection and the delay time of OBU vehicles. We compared each result with a delay time of fixed time signal control. In addition, we changed random seeds of vehicles generating distribution, and simulated each of the three cases. The following results are the mean values.
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Figure 5: The total delay time of whole traffic flows in comparison with the result of fixed time signal control.

Figure 6: The total delay time of OBU vehicles turned to right in comparison with the result of fixed time signal control.
At an intersection where right turn traffic influences the whole traffic, we found that it is effective in shortening the total delay time of the whole intersection when utilizing RT vehicles data with the ITS radio communication systems for actuated right turn signal control. Generally, for OBU vehicles, the delay time was shortened. Moreover, even if the vehicle positional data included in RT vehicles were accurate within about 30 meters, we could confirm the effectiveness.

**Consideration**

*Application to Actuated Right-turn Signal Control Using RT Vehicles Data*

This simulation has shown that we can improve the total delay time of whole traffic flows in the intersection with actuated right turn signal control in application of I2V cooperation systems even if OBU vehicles were only 1 percent of traffic flow (Figure 5). It means that the application to actuated right turn signal control of DSSS I2V cooperation systems is effective in terms of few OBU vehicles. In addition, when the ratio of OBU vehicles is more than 5 percent, improvement has stopped increasing. It is thought that the right turn signal phase will be prolonged by the maximum 5 seconds in almost congestion traffic conditions (Figure 7).

*Affect of Vehicles Position Accuracy*

This simulation has shown that even if the accuracy of vehicle position of data increases, difference in whole intersection hardly changes. It suggests that data from OBU vehicles can be applied to actuated right turn signal control even at the “valley” of tall buildings, where
positioning accuracy by a GPS is generally worse. We are also developing a detection algorithm of right turn vehicles using ITS radio communication.

**Conclusion and Future Works**

Through actuated right turn signal control using vehicle data transmitted from their ITS radio OBU for the DSSS, we found effectiveness in shortening the total delay time of the whole traffic of the intersection through those simulation cases. It showed that we could reduce the delay time even in the case of a ±30 meters difference given for vehicle positions. Moreover, we assumed that we would increase the effectiveness even in the early stage in similar traffic conditions we simulated, because the lower rate of OBU vehicles, such as 1 percent, was able to reduce the delay time of traffic as a whole. We are developing right turn vehicles detection algorithm using RT FCD now and participating in a field verification test this year and will show you the results in 2013 at ITS WC Tokyo.

**Acknowledgements**

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**References**