Low-Carbon Emission Driven Traffic Speed Optimization for Internet of Vehicles

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Abstract. Climate change has become a worldwide concern. Reducing CO2 emission is a major challenge for road transportation sector and is of critical importance. This paper, after studying and analyzing the influence of speed on vehicle CO_2 emission, proposes a recommended speed calculation scheme based on IoV to obtain vehicle speed and traffic signal phase information. In the recommended speed scenario, the vehicle is informed of the traffic phase information before arriving at the intersection and can set and optimize the current speed. This paper analyzes the three different status of traffic lights and studies the speed that should be adopted in each status. Under the proposed scheme, the recommended speed helps the driver to reach the destination with higher driving efficiency. The average wait time at red traffic lights is shorter than at speeds that are not recommended, resulting in reduced total travel time, higher uninterrupted pass rates, and decreased vehicle fuel consumption and CO_2 emissions.

Keywords: Internet of Vehicles · Speed optimization · CO_2 emissions mitigation · Traffic management

1 Introduction

Climate change and global warming has become a worldwide challenge. Climate change, as a result of human activities, can be mainly attributed to emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) from fossil fuel utilization (Javid et al. 2014).

The transportation system is one of the causes that are largely responsible for the depletion of fossil fuels, the environmental contamination and the climate warming in recent decades (Gasparatos et al. 2009; Lim and Lee 2012). At present, fossil fuels take nearly 80% of the primary energy consumed in the world, of which up to 58% alone are consumed by the transport sector (Salvi et al. 2013). Trucks and passenger vehicles largely contribute to the bulk of GHGs emissions (Chapman 2007; Hensher 2008; Javid et al. 2014; Ong et al. 2012). As for China, there has been a rapid increase annually and it is expected to keep growing, particularly in road transport sector (Lin

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and Xie 2013), which reflects the importance of traffic management and optimization in achieving long-term CO_2 mitigation.

New technologies for speed optimization control and traffic management are critical to lower transport emissions. Apart from the widely discussed low carbon vehicle technology, driving patterns and driving speed, including daily driving distance and driving condition would influence the emissions of vehicles (Karabasoglu and Michalek 2013; Kelly et al. 2012; Neubauer et al. 2012; Raykin et al. 2012; Traut et al. 2012). It is of interest to transportation planners, environmentalist, economists and government officials whether there are possible means that could ease the burden of emissions reductions in the transportation sector, particularly those emissions generated by road transportation.

Internet-of-Vehicles (IoV) based low carbon transportation management system is a crucial path to lower CO2 emissions. IoV arises from Internet-of-Things (IoT), in which a great many devices on the Internet are different protocols and standards (Gubbi et al. 2012). It is called IoV when every interconnected devices are recognized as vehicles. IoV can be applied to data communication for healthcare, safe driving, infotainment, energy saving and pollution reduction services (Kumar et al. 2015). Recent studies have shown that IoV technology can be applied to driving speed optimization, enhance energy efficiency and reduce CO_2 emissions (Bodenheimer et al. 2014).When IoV becomes integrated with the transport sector, intelligent low carbon traffic management systems aiming at emission mitigation is quite probable. Using dynamic and ubiquitous connectivity, IoV is capable of detecting traffic movement, process incoming information, relay information to drivers or traffic managers, make their decision and behavior more eco-sustainable, optimize their vehicles' speed for energy efficiency, encourage drivers to avoid aggressive and precarious driving behavior, such as sudden stop and go, and arbitrary speeding and idling, so as to reduce GHG emissions, enhance energy efficiency, and prompt a lower carbon path (Barkenbus 2010; Black and Geenhuizen 2006; Grant-Muller and Usher 2014). Therefore, by means of IoV we will be able to address issues such as energy deficiency, millions of tons of CO_2 emissions, and smooth road traffic (Guerrero-Ibanez et al. 2015).

Rapid acceleration, stop-and-go and traffic jams will cause massive carbon dioxide emissions. There are a large number of signal intersections in urban roads. Due to the periodic interference of their control signals, vehicle speed fluctuations will occur, leading to the decrease of vehicle traffic efficiency and the increase of pollutant discharge. Therefore, in order to avoid sudden acceleration, deceleration, idling and other driving behaviors, so as to improve the traffic efficiency at signalized intersections and the energy-saving and emission reduction effect of vehicles, we proposes a solution to calculate the recommended speed in IoV environment.

Actually, many research efforts have been exerted on IoV based technology aiming at reducing vehicles energy consumption and CO_2 emissions. Systems that uses IoV based traffic signal or mobile system were designed to guide drivers' decisions for the CO_2 emissions reduction, as well as the stop-starts and the accelerations frequency minimization (Dobre et al. 2012). Likewise, a scheme shortening traveling time to destinations and reducing CO_2 emission was proposed to reckon the recommended speed. (Li et al.

2013). An architecture was designed to provide alternative vehicular routes, aiming at lowering of energy consumption and journey time (Stolfi and Alba 2014).

As for exploring algorithms that apply traffic signal data to lessen CO_2 release. Critical aspects considered involve intelligent traffic management with the major challenge of CO_2 emissions mitigation. A function helping lowering emissions was proposed to calculate the optimal cycle length and green time segmentation (Ma and Nakamura 2010). In recent years, an intelligent traffic signal management approach was developed for urban traffic emission reduction (Li et al. 2015). A method was developed to minimize the stops frequency and waiting time for private vehicles (Dujardin et al. 2015). Moreover, a methodology was presented in which signal timings Pareto Fronts containing mobility, safety, and environment, are optimized (Stevanovic et al. 2015).

In this paper, we propose a low-carbon emission driven traffic speed optimization scheme, which is based on IoV to obtain vehicle speed and phase information of traffic signals. So as to reduce CO_2 emissions and increase energy efficiency of vehicles.

The remainder of this article is organized as follows. Section 2 illustrates the interaction between vehicles and traffic signals within IoV. Section 3 introduces the simulation framework of traffic flow-CO_2 emission. Next, Sect. 4 elaborates on the impact of speed on vehicle CO_2 emission. Then, Sect. 5 proposes the recommended speed calculation scheme. Finally, simulation results are presented and discussed in Sect. 6, and conclusions are arrived at in the Sect. 7.

2 Interaction Between Vehicles and Traffic Signals Within IoV

It is predicted that more than 24 billion "things" are expected to be interconnected by 2020, with vehicles occupying an important place (Dua et al. 2014). As more and more vehicles are connected to the IoT, IoV is in the boom (Yang et al. 2014). IoV, consisting of integrated users, vehicles, things, environment and networks, is a dynamic mobile communication system characterized by the collection, sharing, handling, calculating and secure delivery of data, and can be developed into the innovative intelligent transportation system (ITSs) (Lu et al. 2014).

There are two main technical areas of IoV: networking and intelligentization (Yang et al. 2014). Based on interaction between vehicles and traffic control infrastructure, vehicles stop frequency can be minimized and waiting queue at traffic lights can be optimized thereby reducing GHG emissions and improving energy efficiency.

This paper presumes that all the signal controllers are geared with roadside units (RSU). Each vehicle is provided with an on-board unit (OBU). OBU regularly transfer vehicle ID, GPS location, travelling speed, direction and status as well as other related vehicle information. RSU, coordinating with the neighboring RSU, gathers the real-time traffic information through integrating the OBUs information to determine the green segmentation and circular length, thus reducing fuel consumptions and CO_2 emissions. As shown in Fig. 1, based on Dedicated Short Range Communications (DSRC) technology, which is a set of standards at the core of automobile safety information exchange (Morgan 2010), OBU and RSU are capable of mutual communication. Each RSU can communicate with the vehicle if it is within the coverage of IoV communication. RSUs can communicate directly to their adjacent RSUs with one-hop connection. Besides, RSUs can also communicate with each other under IoV. By building up a regional traffic control center that enables two-way communication with each individual RSU, the RSUs are able to communicate with others even these RSUs are far apart. In most cases, the vehicle is associated with a RSU when it is within the coverage area of this RSU. Due to the massive deployment of RSUs, IoV is able to provide nearly seamless coverage for the vehicles that are driving on the road. To this end, IoV can implement handover between adjacent RSUs that hence guarantees the continuous connection for the moving vehicles (Dua et al. 2014; Yang et al. 2014).

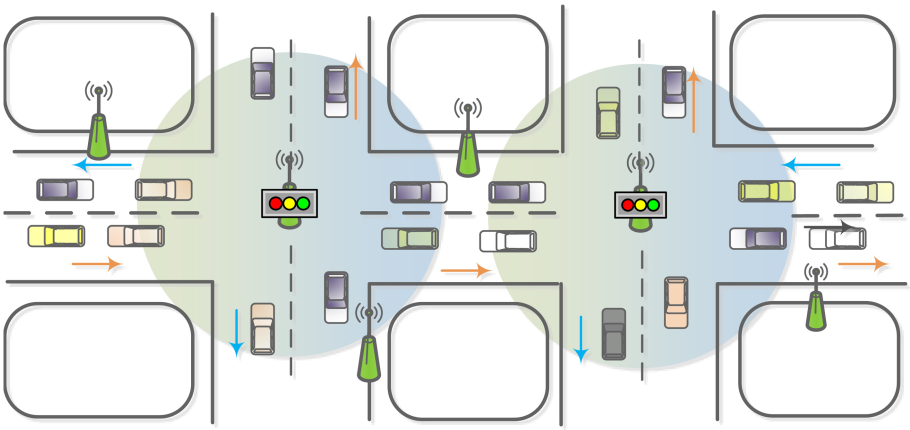

Fig. 1. Interaction between vehicles and traffic signal

As shown in Fig. 1, the RSU at an intersection, while sending packets periodically, corresponds with vehicles in all directions. Once the vehicle enters this range, it receives information from the intersection RSU broadcast, and sends its position, speed, and direction information to the RSU via a packet. After receiving the packet, the RSU sends the data to the traffic control center via the physical device. After receiving related information, the OBU will analyze and provide a recommended driving speed. This speed helps the driver to reach the destination with higher driving efficiency, thus enhancing the traffic efficiency at the signal intersection and the vehicle's energy conservation and emission reduction effect.

The IoV architecture is used for sharing road traffic flow data with adjacent intersections and for the whole city's traffic management as well. One intersection will send its road traffic data to its neighbor, and in turn these data will help the neighbor generate a better traffic signal cycles for vehicles. Through the communication module, adjacent intersections will cooperate with one another to smooth vehicle flow and alleviate traffic congestion.

3 Simulation Framework of Traffic Flow-CO_2 Emission

The simulation framework of traffic flow-CO_2 emission (Fig. 2) has the following features.

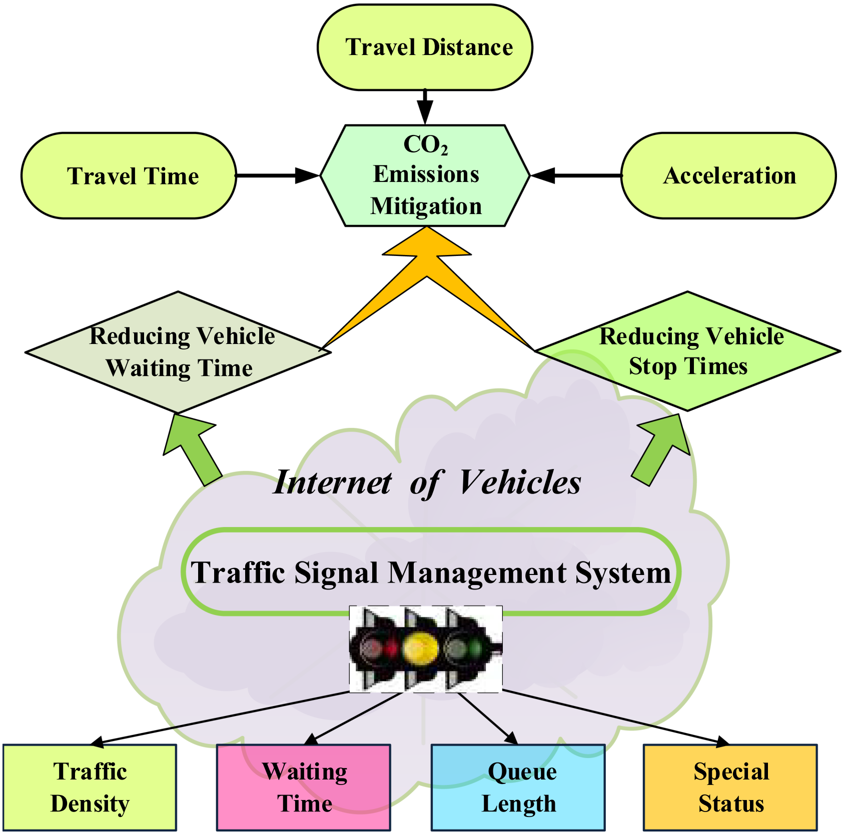

Fig. 2. Simulation framework of traffic flow-CO_2 emission

This paper introduces a CO_2 emission-estimation model, as shown in Eq. (1) and (2) to illustrate the relationship between CO_2 emissions and vehicle motion status(Suzuki and Horiuchi 2005).

$$E = 0.3K_C T + 0.028K_C D + 0.056K_C A \tag{1}$$

$$A = \sum_{k=1}^{n} \delta_k \left(v_k^2 - v_{k-1}^2\right) \tag{2}$$

In Eq. (1) and (2), E signifies the CO_2 emissions [g]. T and D indicate the travel distance [m] and travel time [sec], respectively. K_c describes the coefficient. A and V_k are the accelerated speed value and the velocity in time k [m/sec], respectively. δ_k would be 1 when a vehicle is accelerating at time k, otherwise it would be 0. In a word, when the travel distance is constant, vehicles CO_2 emissions largely rest on the driving time and accelerated speed value.

4 Impact of Speed on Vehicle CO_2 Emission

CO_2 emission of vehicles is usually related to average speed. Researchers often use average speed as a measure of traffic performance. Low average speed generally means stop-and-go traffic. Even if they do not travel very far, vehicle emissions are quite high;

When the vehicle stops and the engine turns, emissions can increase indefinitely. When vehicles travel at higher speeds, the engine loads are higher, which requires more fuel consumption and leads to higher CO_2 emissions.

Based on the typical speed-emission curve in reality, which can be used to test the impact of different traffic operation management technologies on vehicle emissions, such as CO_2 emissions. Several important conclusions can be drawn. 1) If congestion causes the average speed of vehicles to be lower than 45, CO_2 emissions will increase, and at the same time, vehicles will spend more time on the road and produce higher CO2 emissions. Therefore, mitigating traffic congestion under this scenario can directly reduce CO2 emissions. 2) CO_2 emissions will be reduced if traffic congestion is alleviated and the average vehicle speed is reduced from over 70 free flow speed to 45–55. If traffic congestion is reduced and the average speed of traffic flow is increased to over 65, CO_2 emissions will increase. 3) Changing stop-and-go driving mode to make the vehicle run at a relatively stable speed can reduce CO_2 emissions.

A representative driving process covers idling, acceleration, cruising and deceleration. The proportion of energy consumption and carbon dioxide emissions at different stages of driving depends on the driver's behavior (such as irritable and mild driving habits), the type of road (such as highways and urban arterial roads, rural and urban) and traffic congestion. CO_2 emissions are different in these four stages. A driving process can be divided into two parts: 1) idling and 2) driving (accelerating, cruising, and deceleration). Engines consume more energy and release more CO_2 at idle than when the vehicle is in motion.

Moreover, reducing waiting time and driving at a constant velocity will result in lower CO_2 emissions, and studies have shown that vehicles have higher emissions when accelerating and decelerating than when idling. Moreover, the most common cause of engine idling is stop-and-go. Because vehicles slow down, stop, and then speed up for a short period. During that time, the vehicle releases more CO_2. Stop-and-go driving styles normally occur when parking or crossing an intersection. in order to reduce energy consumption and exhaust emission, it is better for vehicles to drive within an effective speed to avoid stopping at intersections.

5 Recommended Speed Calculation Scheme

5.1 Road Condition Detection

Road conditions include current vehicle velocity, vehicle spacing, and vehicle distance to destination. Traffic signal information should also be included when vehicles arrive at intersections.

5.2 Information Exchange

RSU and OBU exchange message via V2V and V2R cycles when the vehicle arrives at the intersection. This information exchange process is shown as follows: First, when the vehicle arrives at the intersection, the on-board unit of the vehicle will send the status information of the vehicle to the traffic signal. Then, the traffic signal receives the information from the vehicle and sends the status of the signal back to the vehicle. The vehicle then receives a response message from the traffic lights, which the unit uses to obtain a recommended speed, which will be provided to drivers.

Therefore, the roadside unit RSUS contain the vehicle's current speed and location information, and the on-board unit will receive the current traffic status information. The current traffic signal information contains the following elements: the traffic signal cycle, the current phase of the traffic signal, and the time left of the current phase. In addition, the on-board unit can also get adjacent workshop spacing.

5.3 Recommended Speed Calculation

The more times the car stops, the more carbon dioxide is released throughout the journey. In this regard, consider giving drivers the recommended speed and speeding through intersections within a reasonable range to avoid unnecessary stops. With this in mind, the vehicle USES the information gathered to calculate a recommended speed that maximizes the vehicle's ability to drive through the intersection in a smooth, low-carbon and environmentally friendly manner. If vehicles cannot cross the intersection with current velocity, take the recommended speed to pass through the intersection, thus reducing the number of vehicle stops.

The distance between the vehicle and the traffic light (d) can be easily obtained through the GPS device. As mentioned earlier, the traffic signal will deliver data packets to the vehicle within communication range. The vehicle is able to compute a recommended velocity after receiving the following message to avoid the vehicle waiting at the intersection.

① Current traffic light status (green, yellow or red).

② Current traffic light status remaining time (L_g, L_r, L_y).

③ The current traffic light cycle CL, the duration of the three stages (T_g, T_y, T_r), among which $C_L = T_g + T_y + T_r$.

In the scheme studied, the duration of red, green and yellow lights is different in each cycle, because the scheme dynamically changes the duration of traffic lights according to real-time traffic flow information. On the strength of this information, the vehicle's OBU device calculates the recommended speed. The maximum speed of the driver is marked as S_{max} and the minimum speed is $\mathrm{S_{min}}$.

In general, vehicle spacing can be divided into two categories: the first type of vehicle spacing is relatively large, so that this type of vehicle can travel freely and is not affected by other vehicles. The second type of vehicle has less space and must follow the vehicle in front of it. Therefore, this type of vehicle cannot exceed the speed of the vehicle in front. Since vehicles can communicate with each other, the front vehicle speed (S_P) can also be obtained. In this scheme, this paper only considers the influence of the front vehicle. Among them, P represents the vehicle spacing is relatively large, $\overline{P}$ represents the vehicle spacing is relatively small.

The following three scenarios demonstrate the calculation of the recommended speed:

$t_0 = d \big/ S_C$: represents the time it takes the vehicle to pass through the intersection at the current speed, distance d.

$t_1 = d \big/ S_{\max}$: refers to the time taken for the vehicle to pass through the intersection at the maximum speed distance d.

(1) The current traffic light is green

① If $L_g > t_0$, it means that the vehicle is sufficient to drive at the current speed through the intersection during the remaining green time, and keep a certain distance between the front and rear vehicles. The recommended speed at this time is the current speed, and its formula is as follows:

$$S_R = S_C \tag{3}$$

② If $t_1 < L_g < t_0$, it means that during the remaining green time, the vehicle is not enough to drive through the intersection at the current speed, but the vehicle can pass at the maximum speed, and the two vehicles keep a certain distance. In this case, the driver needs to accelerate to the maximum speed, so the recommended speed is the maximum speed. The calculation formula is as follows:

$$S_R = S_{\max} \tag{4}$$

③ If $t_1 > L_g$ means that the vehicle cannot pass through the intersection with the maximum speed in the remaining time, then the vehicle needs to wait for the next cycle. To do this, the vehicle must slow down and wait for at least one red light and one yellow light, as shown below:

$$S_R = \min\left(\max\left(\frac{d}{\left(N_g - 1\right) \cdot C_L + L_g + T_y + T_r + M - T_D}, S_{\min}\right), S_F\right) \tag{5}$$

Where, $N_g = \frac{d/S_F - L_g}{C_L}$ represents the number of traffic signal cycles that vehicles need to wait for during the green light period.

④ If the space between the two cars at this time is relatively small, so the vehicle speed is not greater than the front of the vehicle speed, the calculation is as follows:

$$S_R = \min(S_P, S_{\max}) \tag{6}$$

(2) The current traffic signal is red

① If $L_r < t_0 < L_r + T_g$, means that after the red light turns to green, the vehicle can reach the intersection at the current speed, and keep a certain distance between the front and rear vehicles. Then the recommended speed is set to the current speed, which is calculated as follows:

$$S_R = S_C \tag{7}$$

② If $L_r < t_1 < L_r + T_g < t_0$, it means that during the remaining red light time plus green time, the vehicle cannot reach the intersection at the current speed but can reach the intersection at the maximum speed, and the two vehicles in front and behind keep a certain distance. In this case, it is necessary to accelerate to the maximum speed. The calculation is as follows:

$$S_R = S_{\max} \tag{8}$$

③ If $t_1 > T_g + L_r + C_L$, it means that the vehicle still cannot reach the intersection with the maximum speed before the traffic light changes from green to yellow, the vehicle needs to wait for at least one traffic signal cycle, and keep a certain distance between the front and rear vehicles. In this case, the car must slow down. S_R calculation is as follows:

$$S_R = \min\left(\max\left(\frac{d}{N_r \cdot C_L + L_r + M - T_D}, S_{\min}\right), S_F\right) \tag{9}$$

Where, $N_r = \frac{d/S_F - L_r - T_g}{C_L}$ represents the number of cycles in which vehicles need to wait for traffic signals during the red light period.

④ If the space between the two cars at this time is relatively small, so the vehicle speed is not greater than the front of the vehicle speed, the calculation is as follows:

$$S_R = \min(S_P, S_{\max}) \tag{10}$$

(3) The current traffic lights are yellow

Compared to the case of red light, the vehicle needs one or more yellow light time. The calculation of the recommended speed is similar to that of the current red light scheme. The calculation formula is shown as below:

① If $t_y + T_R < t_0 + T_R + T_G$

$$S_R = S_C \tag{11}$$

② If $L_y + T_r + T_g < t_1 < L_y + C_L$

$$S_R = S_{\max} \tag{12}$$

③ If $L_y + C_L < t_1$

$$S_R = \min\left(\max\left(\frac{d}{N_y \cdot C_L + L_r + M - T_D}, S_{\min}\right), S_F\right) \tag{13}$$

Where, $N_y = \frac{d/S_F - T_r - L_y - T_g}{C_L}$ represents the number of cycles in which vehicles need to wait for traffic signals during the yellow light period.

④ If the space between the two cars at this time is relatively small, so the vehicle speed is not greater than the front of the vehicle speed, the calculation is as follows:

$$S_R = \min(S_P, S_{\max}) \tag{14}$$

In Formula (5), (9), (13), T_D represents the transmission delay between the RSU of traffic signal as well as the OBU of vehicle. M represents the time it takes the vehicle to convert from the current speed to the recommended speed.

6 Simulations and Results

This section, based on MATLAB and VISSIM simulation software, is mainly to carry out experimental simulation of speed optimization control, and compare the experiment with no recommended speed, so as to appraise the effect of the proposed solution.

6.1 Simulation Settings

This paper adopts the scenario in Fig. 3, where Road R1 and R2 are the main roads, with a larger traffic flow than R3 and R4, and the driving route is from S to D. When a vehicle passes through an intersection, the driver receives a recommended speed.

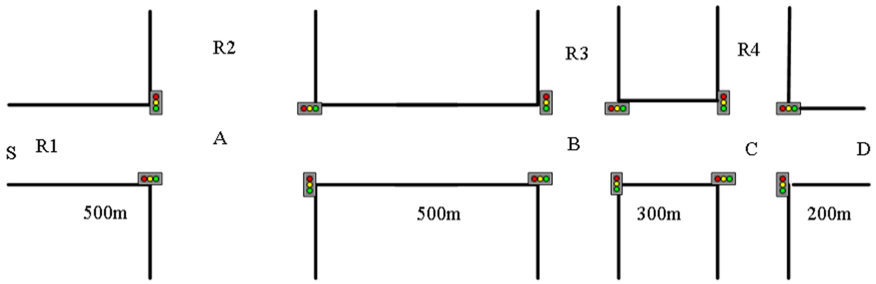

Fig. 3. Simulation scenes

In the experiment, the timing method is used to compare the recommended speed and verify the CO_2 emission of vehicles. The main related parameters are shown in Table 1 below:

Table 1. Simulation parameters

Parameters	Values	Parameters	Values
R1A (green, red, yellow)	(55, 60, 5)	R1B (green, red, yellow)	(55, 50, 5)
R2A (green, red, yellow)	(55, 60, 5)	R3B (green, red, yellow)	(45, 60, 5)

(*continued*)

Table 1. (*continued*)

Parameters	Values	Parameters	Values
R1C (green, red, yellow)	(55, 30, 5)	R4C (green, red, yellow)	(25, 60, 5)
A area coverage	12×12 m^2	B area coverage	12×6 m^2
C area coverage	12×4 m^2	Maximum speed S_{max}	60 km/h
Minimum speed S_{min}	10 km/h	Mobility models	Car following model
Vehicle speed	10–60 km/h	M	3s
T_D	0 s		
Traffic flow	50, 100, 200, 400, 600, 800, 100 veh/h		

6.2 Simulation Results and Analysis

Figure 4 and 5 show that compared with no recommended speed, vehicles with recommended speed can drive across the intersection with shorter waiting time and less stops. Moreover, vehicles with the recommended speed will have less waiting time than

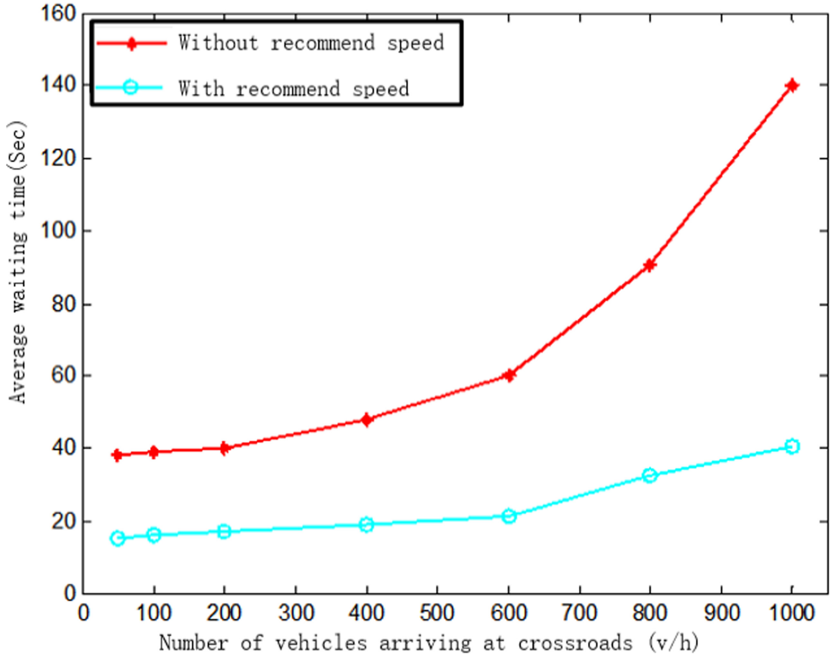

Fig. 4. Average waiting time for vehicles from S to D

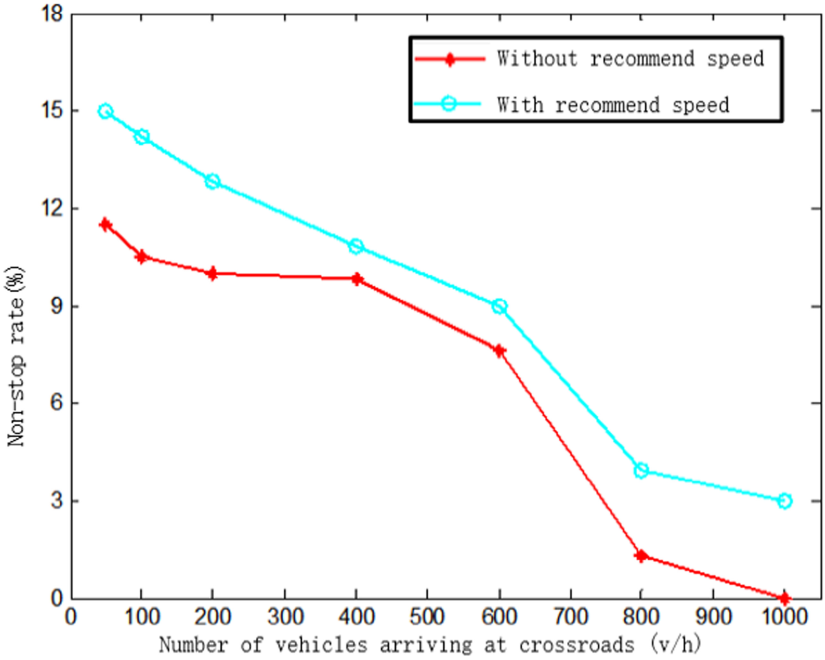

Fig. 5. Average non-stop rate for vehicles from S to D

vehicles with small traffic flows. At the same time, the traffic flow is low; the vehicle stop rate can be greatly reduced.

Figure 4 shows that when the number of vehicles reaches 1000/h, the non-stop rate of vehicles without recommended speed is 0, which means that every vehicle needs to stop, while 3% vehicles with recommended speed method do not need to stop. Therefore, the driving efficiency can be greatly improved by the recommended speed.

As stated before, a calculation model is used to calculate CO_2 emissions. The driving distance, driving time and instantaneous speed of vehicles all affect CO_2 emissions of vehicles. The vehicle can avoid unnecessary stopping by adopting the recommended speed (S_R), such as $S_{min} < S_R < S_{max}$. If the vehicle inevitably comes to a stop at an intersection, it is necessary to adjust the speed to S_R by reducing the number of useless vehicles at high speed. The purpose is to mitigate the acceleration of the vehicle.

The S_R is calculated to achieve the maximum possible speed through the intersection without stopping. Figure 6 shows the amount of CO_2 released by vehicles with no recommended speed higher than those with recommended speed do.

With the increase of the flow of traffic, the amount of CO_2 release growth of the vehicle with recommended speed is not big. The amount of CO_2 released growth of the vehicles with no recommended speed in the case of light traffic flow is also not big. However, when it is in the case of large traffic flow, such as traffic flow reaches 800–1000/h, the release of CO_2 would reach a new peak.

As can be seen from the above figures, with the increase of traffic flow, compared with the speed without recommendation, the average waiting time of vehicles passing the

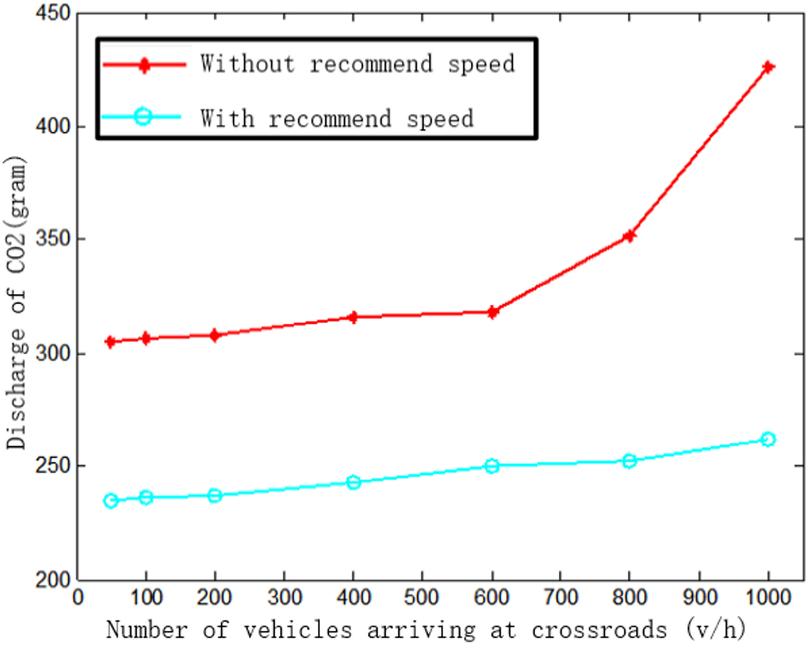

Fig. 6. CO_2 emissions for vehicles from S to D

intersection will be shorter, so the total driving time will be reduced and the uninterrupted pass rate will be higher. At the same time, vehicle energy efficiency will be enhanced, which will cut down CO_2 emissions.

7 Conclusions

Climate change and energy shortage have become a serious problem for many countries. Among the primary GHGs responsible for human-induced climate change, CO2, as the main GHGs component, has the greatest impact on the man-made climatic variation (Javid et al. 2014; Zhi et al. 2013). Therefore, reducing CO_2 emission is a major challenge for road transportation sector and is of vital importance.

There are a large number of signal intersections in urban roads. Due to the periodic interference of their control signals, vehicle velocity fluctuations will occur, leading to the decrease of vehicle's traffic and energy efficiency and pollutant discharge when driving across the intersections.

Based on this, in order to avoid sudden acceleration, deceleration, idling and other driving behaviors, so as to improve the traffic efficiency at signalized intersections and the energy-saving and emission reduction effect of vehicles, this paper proposes a recommended speed calculation scheme, which is based on IoV to obtain vehicle speed and phase information of traffic lights.

Under the recommended scheme, drivers would be notified to drive with the optimized speed. This speed helps the driver to reach the destination with higher driving efficiency, thus improving the traffic efficiency at the signal intersection and the vehicle's energy conservation and emission reduction effect. The average wait time at red traffic lights is shorter than at speeds that are not recommended, resulting in reduced total travel time and higher uninterrupted pass rates. At the same time, vehicle fuel consumption will be reduced, which will make for lesser CO_2 emissions.

The benefits observed have shown the low carbon potential of an IoV based intelligent traffic signal management system. This implies that the climate and energy costs can be reduced without affecting traffic fluidity. However, CO_2 or GHGs cannot be mitigated by simply exploiting traffic management system. This study have shown that for a given conditions there exist the possibility to cut down environment costs by referring to the IoV based intelligent traffic management solution, even at a micro-level. The results of our simulation present powerful arguments for the strategic development and diffusion of the IoV based traffic management systems, which can hardly do without the support and cooperation of the government, other institutions and the public.

Political will and commitment is of critical importance for the development of low carbon traffic system (Yin et al. 2015). Clear local political support combined with the cooperation of related institutions, such as setting up infrastructure development programs and promulgating beneficial regulations, is one channel to provide more consistent assist and planning for developing and popularizing IoV based low carbon traffic management system. As low carbon and sustainable development is interdisciplinary, and IoV based transport system is inseparable from scientific planning and construction of urban infrastructure emphasizing the concerted effort so as to realize desired outcomes (Baltazar et al. 2015).

Although, this paper presents evidence that there are optional paths for achieving the low carbon future without sacrificing the mobility, convenience, comfort and safety. There are still some area worth future work and improvement. The CO_2 emission model used in this research is relatively simple one, which does not take relevant factors into consideration, such as vehicle type, vehicle age, vehicle condition, driving habits and infrastructure features. Cautions need to be taken when the proposed approach is applied to a specific vehicle in a specific infrastructure environment (Li et al. 2014). So, further investigations on how to incorporate more advanced CO_2 emission estimation model is necessary (Rakha et al. 2011).

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