Model Based Traffic Light Control For Reducing CO_2 Emissions In Vehicles

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Abstract: Generally, vehicles' stop-and-go driving will consume more fuel and emit more co2 than constant speed of vehicles .To reduce vehicles' CO_2 emissions vehicles' travel should be smoothed by reducing the stop-and-go times. In this paper, three techniques are proposed to realize dynamic traffic light control for smoothing vehicles' travel. In technique-1, an intelligent transportation system (ITS) employed for collecting road traffic flow data and calculating the recommended speed. In technique-2, radio antennas are installed near the traffic lights. Traffic flow information can be obtained by wireless communications between the antennas and ITC devices. In technique-3,a branch-and-bound based real time traffic light control algorithm is modeled to smooth vehicles' travels. After smoothing vehicles' trip, more vehicles can pass intersections with less wait time and reducing short-times stops; therefore, CO_2 emissions in the vehicles' can be reduced. Simulation result proves that the proposed scheme performs much better than the adaptive fuzzy light control method: The average waiting time, start-and-stop times, and CO_2 emissions are efficiently reduced, and the nonstop passing rate is greatly improved.

Key words: Branch and bound (BB), Emissions of CO_2, Intelligent transportation system (ITS), Three-technique open model, speed control.

I. INTRODUCTION

Nowadays, the effect of global warming has seriously become a worldwide concern. It involves issues such as the rising of sea level problem and snow slides. During the past 100 years, the sea level has raised between10 and 25cm [1]. Our environment has changed through heat waves or extreme weather [2], [3]. To minimize the speed of our living environment's deterioration, the emissions of CO_2 reduction has become urgent. As one of the main sources of CO_2, vehicle emissions have become more serious due to frequent increase in the number of vehicles in the worldwide [4]. A typical trip consists of idling and driving periods. The proportions of the trip spent in these stages will be based on the driver's behavior, the road type and the traffic error control. The emissions of CO_2 rates are different in these stages. The two parts of the trips are 1) idling and 2) driving. The driving period consists of cruising, accelerating, and deceleration [5]. Barth et al. proposed that[6], during an idling period, the engine would consume more fuel and emissions of CO2 is more than in a cruising period; on the other hand, less waiting times and a constant-speed driving style would lead to less CO_2. A study in [7] indicated that CO2 emissions rate is high in decelerating than accelerating.Furthermore [6], implied that the major reason for engine idling is a stop-and-go driving style, because in a lower time period, drivers have to accelerate to go and then decelerate to stop. During this period, vehicles' CO_2 emissions are more. E.g., taxies waiting in queues for pick up the passengers.

One of the important methods for smooth travel is the traffic light control model. The commonly used control scheme is the fixed-time control [8], but it cannot produce the required results. Adaptive traffic lights depend on wireless communication with the vehicles employ greater flexibility than other methods.

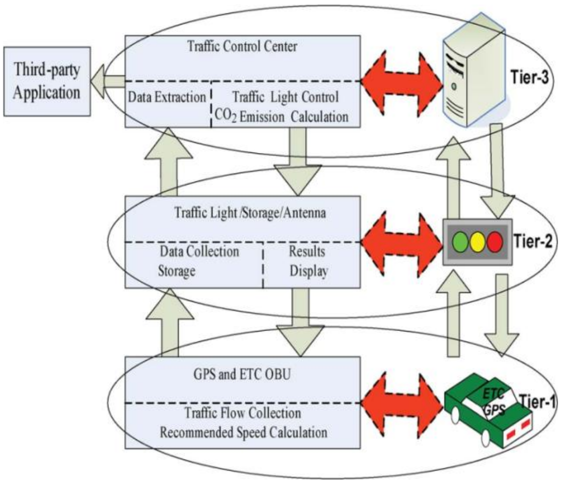

Fig . .1. Three-technique open traffic light control model

As above mentioned, traffic light control plays very major role in smoothing travels by minimizing vehicles' waiting time and the number of stoppages[9]. Oda et al. carried out experiments a microscopic simulation model to obtain the traffic flow to reduce the waiting time in [10] and to calculate the CO_2 reductions in [11]. However, the result was unclear, and it is not suitable for real-time applications. Alsabaan et al. had carried out by using new protocol for reducing fuel consumption and emissions in [12].

With the development of ITS devices, it is widely used for highways by nonstop passing of vehicles [13]. In previous paper, we employed Electronic toll collection vehicles to communicate with traffic lights to obtain real-time traffic flow information and tree based algorithm was proposed to minimize the waiting time.

II. SYSTEM MODEL

In this paper, a three-technique open model is proposed for adaptive traffic light control, which is mainly concerned at smoothing vehicles' travels. In this model, we suppose that all vehicles have installed the Liquid Crystal Display (LCD) devices and ITS devices called on-board units (OBUs).LCD devices are used to collect the information, such as the speed of the current, the distance, deceleration, acceleration and the moving directions. Then, in the traffic control center, traffic lights' cycles are adjusted based on the received detected traffic flow signal by a certain traffic light control algorithm. Last, an existing emission of CO_2 is used to calculate the CO_2 amounts

Three-Technique Open Traffic Light Control Model:

1) Introduction of the Three-Technique Open Model: From a macroscopic view, a three-technique open model for adaptive traffic control is shown in figure. We suppose the antennas are installed near the traffic light to collect the traffic flow information and the antenna has its own maximum distance, which is based on its performance

a) Technique-1: The main function of technique -1 is mainly concerns collecting traffic flow information data, receiving traffic light phase data, and calculating the recommended speed. In this technique, vehicle state information will be obtained from LCD devices. The ITS OBUs devices can communicate with the traffic lights to send the current information to the traffic control center and receive the data. Based on the recommended speed, the drivers can modify or keep the current speed to pass through the intersections with less waiting time or less number of start-and-stop times.

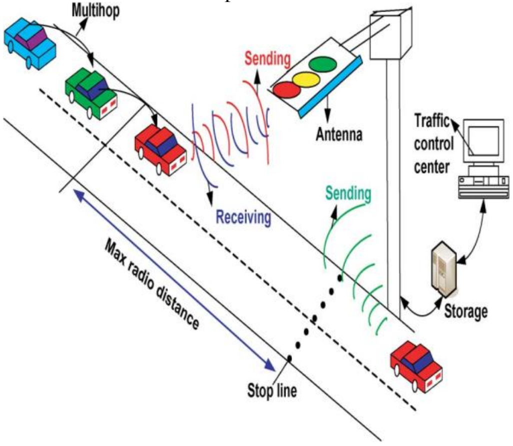

Fig . 2. ITS based traffic flow detection process

b) Technique-2:In Technique-2 is mainly responsible for receiving and saving traffic flow data and then sending the control results to the ITS OBUs. This technique consists of following three parts 1) antennas, 2) storage, and 3) traffic lights.

As aforementioned in technique-1, the ITS OBU devices and antennas can communicate with each other by wireless communications: therefore, the real time traffic flow information can be sent to the lights. Meanwhile, the traffic control results will be sent to the ITS OBUs, and then, drivers can know the traffic light phases in time. The purpose of the storage is to save the traffic flow data that received. The traffic lights are the displays that show these control results.

c) Technique-3: Technique-3 takes responsibility for data processing which can be divided into three parts.

The first part is extraction of data. As vehicles regularly send the traffic flow information to the antenna before passing through the junction, it may cause some problems. For example, the same data may be received many times and the recent data may exist in the storage. Therefore it is necessary to extract the required data from the received data.

The second part is traffic light control. The traffic control center periodically sends the latest traffic flow data from the storage and calculates the accurate light-changing policy for this period. The optimal light-changing policy will updates new traffic flow information acquired; therefore, this shows that it is a dynamic control process. In other words, the control center will control the duration time of red or green light's phase according to the fluctuation of traffic flow. The optimal light-changing policy would be estimated by a control algorithm that can realize the lowest waiting time. Since ours is an open system others traffic light control algorithms can be used in this section, such as dynamic-programming- based fuzzy control in [14] and the decision making- algorithm in [15]; all these algorithms are acceptable for out model. Working with new control algorithms according to the intersections' road situations is also available. In the following section we will provide a branch-and- bound (BB) based control algorithm.

The third part provides an open interface for third-party applications. Vehicle's information can be shared by third-party applications. For example vehicles manufacturers or magazines may use these data are used to analyze which type of vehicle used and popular brands. Moreover, real-time road traffic data can be drawn into a dynamic traffic flow map on the control center. Based on this map, the city's traffic monitor center can easily manage the traffic. In addition, the CO_2 reductions can be used to enhance the quality of city's environment.

2) Traffic flow detection process: As aforementioned, we suppose that all the vehicles have installed the ITS devices. In the following paragraphs, we will introduce the traffic flow detection process between

the vehicles and antenna through wireless communication.
To easily understand this process, we use three stages to describe it.

First, when a vehicle reaches an intersection, they send the road traffic flow data to the antenna. If the vehicle comes under the coverage area of antenna, the OBU devices can directly communicate with the antenna. However if the vehicle is not present under this area, it has to send the data to the front vehicles, which can switch over the data to the antenna by multihop communication. Obviously, each vehicle performs the following two functions: 1) to relay other vehicles' states data and 2) to send its own data. The OBUs periodically broadcast the vehicles' motion and vehicles approach the radio coverage area, the antenna receive these states data; thus the road traffic flow information can be acquired. After data extraction, the traffic control center in technique-3 periodically picks up the traffic flow information data from the storage in technique-2. In this process, the control center acquires the recent road traffic flow before vehicles arrive at the stop line; in other words, the control center can "predict" the arriving vehicles' queues.

Second, after the traffic control center estimates the optimal light duration time for the next light cycle, the antenna sends the control results to the vehicles. After receiving the information from the light, OBUs will calculate a recommended speed for drivers. Then the drivers can alter to recommended speed or maintain current speed to pass through the intersections. The purpose of calculating the recommended speed is mainly concerned on the following two aspects: 1) it is to inform the drivers to how they can pass through the junctions with less waiting time and with less number of stops, and 2) it is aimed to avoid entering into the confused zone by changing the speed for the drivers' safety.

Third, after the vehicles have passed through the intersection, they also necessary to send motion states data to the antenna so that the data can be shared by the following intersections. This approach provides useful traffic flow data around the city. In short, this traffic flow detection process allow ITS devices that want to pass the intersections to send their "requests" to the traffic light , and then, the light adaptively changes its cycle and time duration according to the requests. But, when vehicles send traffic information to the traffic lights, the signal interfaces among vehicles would appear. Although in technique-3, the data extraction section can solve this problem in a certain degree; this problem cannot ease to zero. Therefore, how we can get a more accurate traffic information through the ITS vehicles and how we can extract the useful information from a mass of received traffic flow data still needs to be done in our future work.

A vehicle's CO_2 emissions are greatly affected by the road and traffic flow conditions. The fuel consumption rates and CO_2 emission rates are based on the type of road conditions. There are two types of roads rural and urban roads. Urban road usually have higher emission rates than the rural roads [6]. Oguchi et al. [16] designed an emission model for estimating vehicles' CO_2 emissions using real time road traffic factors. The model is represented by the following formulas:

E	CO_2 emissions [g];
K c	Coefficient between gasoline consume and CO_2 emissions;
D	Travel distance (in meters);
T	Total travel time for the distance D (in seconds);
Aee	Acceleration energy equivalent (in square meters per square seconds);
v k	Speed at time k (in meters per second);
σ k	σ k =1 if v k >v k-1 ; otherwise, σ k =0.

$E= Kc(0.3T=0.028D+0.056Aee)$ (1)
$Aee=\sum \sigma k(vk2-vk-12)$ (2)

The value of Aee can be calculated by the vehicle travel mode in acceleration and deceleration, as shown in (2). Equation (1) represents that, when the D is fixed, a vehicle's CO_2 emissions mainly related with the T and speed v. Hence, when the road conditions are fixed, vehicle's CO_2 emissions is limited to T and v. Even for the few vehicles under the same road condition, T and v will be different based on the different realistic traffic conditions. Because the traffic condition will affect the vehicle's speed, acceleration, deceleration, the travel time will also changes.

III.CONTROL ALGORITHM FOR SMOOTHING TRAVEL

To realize the aim of reducing vehicles' CO_2 emissions, we plan to smooth vehicles' travels by the following two ways: 1) to control the traffic lights to let vehicles pass the intersections with less waiting time, which goals at reducing the idling period CO_2 emissions; and 2) to recommended a suitable speed before entering the intersection, which is used to reduce vehicles' driving period CO_2 emissions.

The algorithms used in this technique are,

Algorithm 1: SBB algorithm—LB searches.

```
time ← LB(root)
Branching (root)
fori ← 2 to (n1 + n2 − 1) do
Branching (min (LB (left node), LB (right node)))
i ← i + 1
time ← (min (LB(left node),LB(right node))
end for
for j ← 1 to activenode do
Branching (list[j])
if LB(node) ≥ time then
_ prune this branch
else if(reach a leaf node)
time ← (min (LB(left node),LB(right node))
if max _red ≥ time ≥ min _green then
time ← time
else if (time ≤ min _green)
time ← min _green
else if (time ≥ max _red)
time ← max _red
```

```
end if
end if
RETURN(time)
end for
```

Algorithm 2: SBB algorithm—Order search [47].

```
Branching (node)
LB (node)
_ use (3) and (4)
CHANGESEQUENCE (i)
_ change the node sequence at i
LB (newnode)
ifi< n1 + n2 − 1 then
list[node] ← max(LB(left node),LB(right node))
_ add active nodes to list
activenode ← activenode + 1
else if (max(LB(left node),LB(right node)) ≤ time
list[node] ← max(LB(left node),LB(right node))
activenode ← activenode + 1
end if
```

A. Traffic Light Control Algorithm

Problem Specification:

When heavy traffic occurs, to evacuate the vehicles in detecting queues, we need to allocate the passing orders of the vehicles. The problem turns out to be an order-decision problem. Here, we adopt a BB [17] method to solve the order-decision problem.

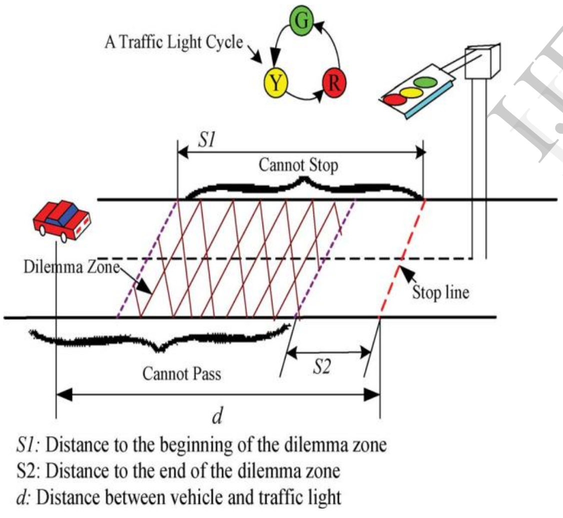

Fig . 3. Distance d and dilemma zone

SBB Approach: The total evacuation phase consists of the following parts: 1) the time of all the detected vehicles' to pass through the intersection 2) the time is wasted on changing the green lights between the roads.

B. Calculating the recommended speed:

The stop-and-go driving style commonly occurs when vehicles prepare to pass through the intersections.

As aforementioned the traffic light will send the result packet to the vehicles. After receiving the packets, the following information can be obtained and then used to calculate the recommended speed.

1) Distance d
2) Current traffic light cycle, current light phase, and duration time of three phases in the current cycle Tg, Tr and Ty, where Ccycle= Tg+ Tr+ Ty;
3) Remaining time of the current light phase Lg, Lr and Ly.

Calculation as follows:
$t0 = d/Scurrent$
$t1 = d/Smax$
Where,
t0= time that vehicle reaches intersection
t1=time that the vehicle pass the intersection
d=distance between vehicle and next intersection
Smax=maximum speed to cover the distance without stopping
Scurrent=current speed of vehicle

Case 1: current light phase is green:

1) If Lg is very long that is $t0 \leq Lg$, then Srec=Scurrent .
2) If $t1 \leq Lg < t0$, then Srec=Smax .
3) If $t1 > Lg$, then SRec = min (max (d/tg,Smin),Smax) .

In the equation, tg stands for

$Tg=(Ng-1)CCycle + Lg + Tr + Ty + M - D$
Where,
$Ng = (t1 - Lg)/CCycle$;
D = transmission delay from signal to vehicles;
M = duration time for vehicles from Scurrent to SRec .

Case 2: Current Light Phase Is Red: The three cases are

1) If Lr< to <Lr + Tg, then SRec = Scurren t.
2) If Lr< t1 <Tg + Lr< to, then SRec = Sm+ax .
3) If t1 >Tg + Lr + Ccycle , then SRec = min(max((d/tr),Smin), Smax) .

In the equation, tr = (NrCcycles + Lr + M – D, and
Nr=(t1 – Lr – Tg)/Ccycle

Case 3: Current Light phase Is Yellow:
1) If Ly + Tr< to _≤ Ly + Tr + Tg, then SRec = Scurrent .
2) If Ly + Tr + Tg< t1 ≤ Ly + Ccycle , then SRec = Smax .
3) If Ly + Ccycle ≤ t1 , then SRec = min(max(d/ty, Smin) , Smax) .

In the equation, ty stands for ty = NyCcycle + Tr + Ly + M – D ,
andNy = (t1 – Tr – Ly – Tg)/Ccycle .
where R1=road1, R2=road 2

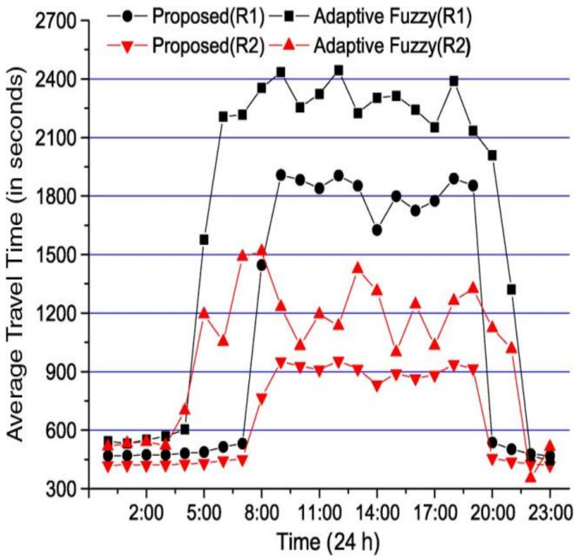

Fig . 4. Average CO_2 emissions from Source to Destination.

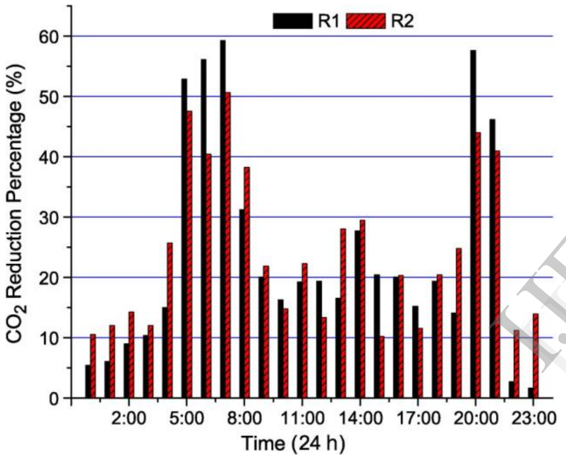

Fig.5. CO_2 Reduction percentage from Source to Destination

IV. CONCLUSION

In this paper a real time applications of traffic light control model has been proposed. This control system was constructed from a three technique open model.technique-1and technique-2 were mainly concerned with road traffic flow detection. A recommended speed calculation was carried out in technique-1, which was used to avoid dilemma zone conditions and unnecessary short time stops. With ITS vehicles the traffic control center in technique-3 could get an accurate result in real time traffic flow information. Considering drivers behavior and toleration times, an improved BB based traffic light control algorithm was designed in technique-3. Less waiting time and least short time stops could be achieved by this proposed method. Thus less CO_2 emissions could also be minimized. Compared with adaptive cruising control the proposed method performed in terms of reducing the vehicles average waiting time, number of stops and emission of CO_2 whereas the nonstop passing rate was also highly improved.

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