Influence Analysis of Real-Time Guidance Information on Travelling Time in Road Networks based on Swarm Intelligence

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***Abstract* — The swarm intelligent such as vehicular ad hoc networks is applied to developing the decentralized advanced transportation information systems, such as real-time traffic guidance. In this paper, an intelligent traffic guidance algorithm is presented based on the swarm intelligent, and the influence of real-time guidance information on travelling time based on vehicular ad hoc networks is discussed. A car agent with the capacity of wireless communication can receive and perform the traffic guidance information in real-time using the adaptive traffic guidance algorithm. An incident scenario is established to evaluate the effect of equipment rate, communication distance and compliance rate on travelling time during traffic guidance. The simulation results illustrated that three factors contribute to characterize the travelling time of local road networks, and have a significant correlation with travelling time. The results also indicate that three factors exist the optimal value, and the perfect guidance effect can be obtained if the appropriate value ranges of equipment rate, communication distance and compliance rate are acquired, for example, the range of equipment rate is 40%~60% in this study.**

Keywords - artificial intelligence; adaptive traffic guidance algorithm; travelling time; data communications; algorithm analysis

I. INTRODUCTION

It is very important that traffic flow is guided using the real-time traffic information when there are traffic congestion and traffic incidents in the road network, which can effectively decrease travel delay[1]. The effectiveness of real-time traffic guidance information has been studied by many researchers, using both analytical and simulation approaches. A few of field tests have also been conducted in such projects as connected vehicle and PROGRAM to explore advanced traffic information system (ATIS) in large-scale networks. Most of the ATIS that have been either investigated or deployed are centralized systems. The occurrence of swarm intelligence technologies such as vehicular ad hoc networks has made the consideration of inter-vehicle communication (IVC) possible as a foundation for developing decentralized ATIS.

The real-time traffic information plays a key role on traffic guidance, and a number of previous studies have investigated the influence of traffic information on route choice and guidance effect[2-3]. The research on route guidance using swarm intelligence was focused on the model algorithms and simulation, and many contributions were obtained. Researchers attempted to apply IVC for traveling time prediction, considering some characters of IVC, such as the number of vehicles equipped with communication devices and communication protocols[4-6]. In addition to the above research works, the traveling time under traffic guidance was analyzed in a few of studies in recent years[7]. Although numerous previous studies have been done for the traveling time research, all of them only focused on the traveling time itself but did not pay attention to the communication routing algorithms that would be essential for wireless communication transmission. Furthermore, those studied were based on the assumption that the success of transmission was 100% within the transmission range, which did not accord with the wireless signal propagation characteristics.

When the vehicle agent has received the guidance information from swarm agents in vehicular ad hoc networks, the vehicle agent would change its travelling route. Then the topology structure of information transmission between vehicles agent might change, the guidance information available for vehicles agent would change. The relationship between guidance information and travelling route is a dual-coupling role. Using the EstiNet simulator, this study evaluated the effects of three factors (equipment rate, communication distance, and compliance rate) on traveling time during the VIC-based traffic guidance. Through establishing the road networks in EstiNet, the traffic flow and information flow were integrated to realize the real-time information exchange between IVC-capable vehicles. This research aimed at analyzing the interactive effect between the three factors and traveling time during the real-time traffic guidance, and identifying the rules of traveling time changes with three factors.

II. METHODOLOGY

This study used the EstiNet simulation software as a tool for data collection. EstiNet is a high-fidelity and extensible network simulator and emulator, which incorporates traffic simulation (e.g., road network construction and microscopic vehicle mobility models) with its existing network simulation, tightly integrates them together, and provides a fast feedback loop between them[8]. With these capabilities, EstiNet now is a useful simulation platform for wireless vehicular communication network research.

EstiNet adopts a distributed architecture, which is a system comprising eight components as shown in Figure 1.

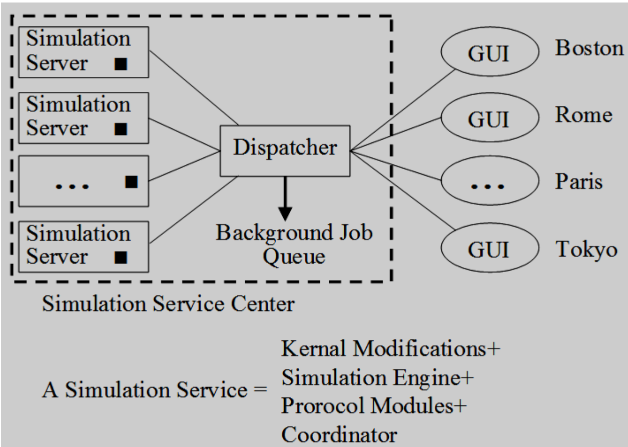

Figure 1. The distributed architecture of EstiNet

In the traveling time experiments, a rectangular undivided four-lane highway was used as a simple road network. Its range is 4200m*2000m with a lane width of 3.75 m. The scenario that the network implements traffic guidance in simulation is shown in Fig. 2. During the course of the experiment, a guidance information transmission vehicle was stopped at a location downstream of intersection A, where the distance between vehicle and intersection A was 1000 m. All vehicles (50 vehicles) on the road run according to the initial path ①. Some sample vehicles were selected randomly to install wireless transceiver model and had the capacity of information receiving and forwarding. When the vehicles with transceiver received the guidance information, they would change the initial path ① at intersection A and follow the guided path ②. Before the simulation, all the vehicles are arranged by the equal headway with the maximal velocity of 18 m/s.

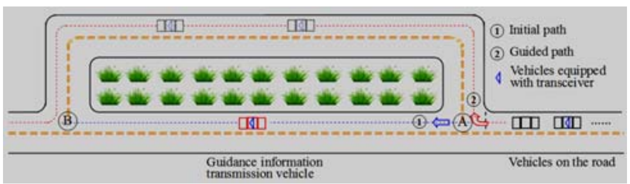

Figure 2. Traffic Scenario Design

Adoptive traffic guidance algorithm under the condition of vehicular ad hoc networks belongs to swarm intelligence. Swarm intelligence is the collective behavior of decentralized, self-organized systems, natural or artificial which was introduced by Gerardo Beni and Jing Wang in 1989. Swarm intelligence systems consist typically of a population of simple agents interacting locally with one another and with their environment. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local, and to a certain degree random, interactions between such agents lead to the emergence of "intelligent" global behavior, unknown to the individual agents. Vehicles in vehicular ad hoc networks are a population of simple vehicular agents with swarm intelligence, which interact each other by inter-vehicle communication.

When the simulation started, all vehicles were arranged upstream of the intersection A with a constant gap of 50 meters in the road networks, as shown in Figure 2. An accident vehicle of red color stopped on the road and transmitted the guidance information uninterruptedly. When the simulation was running, 50 vehicles were traveling according to the initial Path ①. Vehicles without transceiver would be approaching the accident vehicle, and stop behind the accident vehicle. Upon entering the communication distance (DC), vehicles with a transceiver, depending on the transceiver equipment rate (RE), could receive the guidance information and forward the information to notice the following vehicles with transceiver. When the following vehicles with transceivers arrived at the intersection A, they would change the traveling path from Path ① to Path ② according to pre-desired compliance rate (RC). The logical relationship of guidance process is shown in Figure 3.

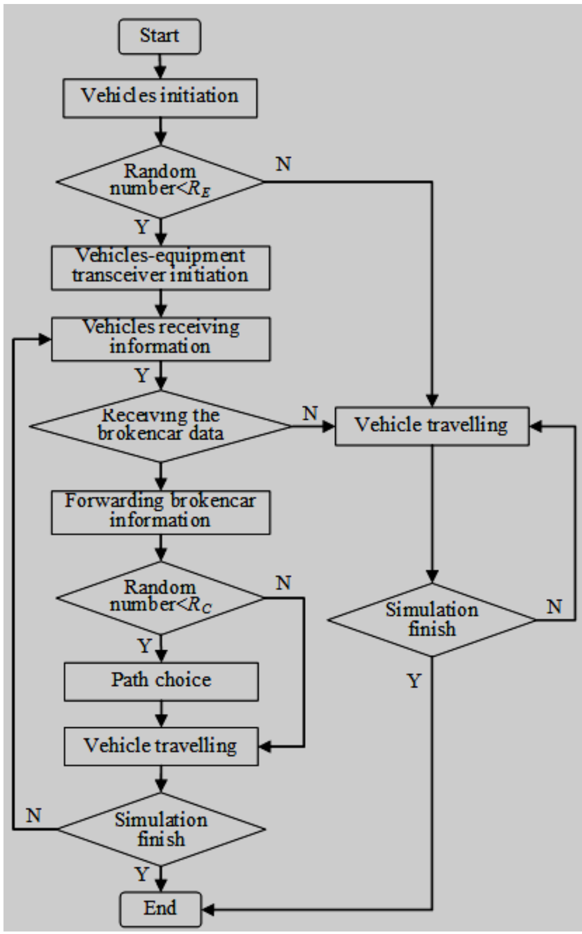

Figure 3. The logical relationship of guidance process

During the course of the simulation, real-time traveling parameters of 50 vehicles were collected and recorded into the Log files. All parameters used in our simulation are summarized in Table 1.

In the simulation experiment, the collected parameters related to vehicle traveling include vehicle ID, velocity, position (x, y, z coordinates) and corresponding arrival time. This paper mainly studies the influence of real-time guidance information on road networks traveling time, so traveling time between intersection A and intersection B under different conditions (DC, RE, RC) was selected as dependent parameter.

The traveling time can be calculated by the Equation (1).

$$TT = \sum_{j=1}^{N} t_j \Big/ N, \quad t_j = \sum_{i=1}^{S_t} \frac{\sqrt{(x_{i+1,j}-x_{i,j})^2 + (y_{i+1,j}-y_{i,j})^2}}{v_{i,j}} \qquad (1)$$

Where, TT is the average traveling time (s); tj is traveling time each vehicle between intersection A and intersection B (s); N is the number of sample vehicles; St is the vehicle j simulation time between passing intersection A and passing intersection B (s); (xi,j,yi,j) are the coordinates of vehicle j on simulation time i (m); vi,j is the velocity of vehicle j on simulation time i respectively(m/s).

TABLE I MAIN SIMULATION PARAMETERS

Parameters	Value	Parameters	Value
Simulation time(s)	700	Simulation step(s)	0.2
Vehicle max velocity(m/s)	18	Vehicle max Acceleration(m/s2)	1
Vehicle max deceleration (m/s2)	-4	Equipment rate(%)	20,40,60,80,100
Communication distance(m)	100,300,500, 700,1000	Compliance rate(%)	20,40,60,80,100
Guidance information transmission duration(s)	0~400	Types of ITS cars	802.11(p) (agent-controlled)

III. EXPERIMENT RESULTS

An ANOVA and correlation were used to investigate differences between factors, as shown in Table 2. The hypothesis testing in the following analysis was based on a 0.05 significance level. Clearly, the traveling time is correlated with all of the three factors.

TABLE I MAIN SIMULATION PARAMETERS

		Equipment rate	Communication distance	Compliance rate
Travell-ing Time	Pearson Correlation	-.654**	-.309**	-.456**
	F-ratio	24.529	4.152	7.966
	d.f.	4	4	4

**. Correlation is significant at the 0.01 level (2-tailed).

The simulation results illustrated that equipment rate, communication distance and compliance rate are significantly associated with the traveling time in local road networks. For a certain communication distance, the traveling time declines with the increase of equipment rate under the different compliance rates. The decline degrees are different: in the case of 700 m communication distance, the decrease proportions of average traveling time are 2.30%, 8.81%, 14.39%, 17.14%, 25.26% respectively, corresponding to compliance rate of 20%,40%,60%,80%,100%; and the traveling time reductions between 20% and 100% of compliance rates are 10.10 s, 19.08 s, 62.07 s, 86.65 s, 109.80 s respectively, corresponding to equipment rate of 20%, 40%, 60%, 80%, 100%, as shown in Fig. 4. It shows that the traveling time has a bigger decline proportion when the equipment rate is in a range of 40%~60%. The results imply that an optimal range for the equipment rate exists in terms of traveling cast. Generally, both traveling time cost and transceiver cost should be considered to achieve the optimal total travel cost when implementing the traffic guidance. Thus, the ratio of vehicles equipping wireless communication transceiver in traffic has a reasonable range to ensure the guidance effect of whole traffic flow.

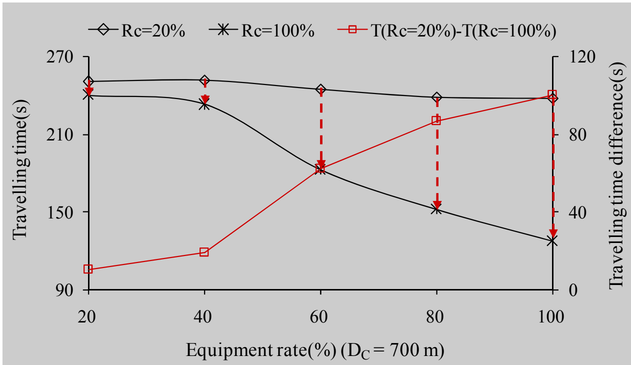

Figure 4. The variation of traveling time difference (TRc=20%-TRc=100%) corresponding to equipment rate of 20%, 40%, 60%, 80%, 100%.

For a certain compliance rate, the traveling time declines with the increase of equipment rate under different communication distances, and there is also a difference in decline degree. Figure 5 illustrates that for compliance rate of 60%, the decrease proportions of average traveling time are 3.80%, 12.99%, 18.01%, 19.58% and 20.69% respectively corresponding to communication distances of 100 m, 300 m, 500 m, 700 m and 1000 m; and the traveling time differences between 100 m and 1000 m of communication distances are 12.49 s, 16.21 s, 44.48 s, 57.96 s, and 37.53 s respectively corresponding to equipment rates of 20%, 40%, 60%, 80%, 100%, as shown in Figure 5. It shows that the traveling time has a larger decline value when the equipment rate is in a range of 40%~60%, which has a same result with Figure 8. Therefore, if the communication distance exceeds the optimal range, the guidance effect for whole traffic flow may be worsened so as to appear the “over-guidance” phenomenon.

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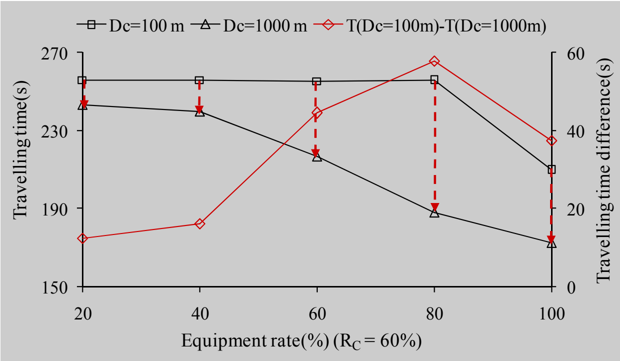

Figure 5. The Variation of Traveling Time Difference (TDc=100m-TDc=1000m) Corresponding to Equipment Rate of 20%, 40%, 60%, 80%, 100%.

IV. CONCLUSIONS

EstiNet network simulator and emulator provide a visual and extensible simulation environment to test Vehicular Ad Hoc Networks. The traffic scenario design and vehicular communication protocol allow researchers to observe the traffic guidance phenomenon, while it is very difficult in a field study since traffic guidance is influenced by the drivers' behaviors and character. In this study, it was found that the traffic guidance effect is influenced by equipment rate, communication distance and compliance rate. The optimal guidance effect can be obtained if the appropriate ranges of equipment rate, communication distance and compliance rate are achieved. For example, the range of equipment rate is between 40% and 60% in this study. For the traffic management, the study results could be used as reference: 1) the ratio of vehicles equipping wireless communication transceiver in traffic has a reasonable range to ensure the guidance effect of whole traffic flow. 2) if the communication distance exceeds the optimal range, the guidance effect for whole traffic flow may be worsened so as to appear the "over-guidance" phenomenon.

The future works include: 1) more objective characteristics of traffic flow will be reflected and the optimal values of equipment rate, communication distance and compliance rate will by studied through increasing the number of sample vehicles; 2) the influence of communication distance on traveling time will be further investigated through adjusting the distance from the accident vehicle to the rerouting intersection A.

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