Physica A 391 (2012) 6137–6145

Contents lists available at SciVerse ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Effect of signals on two-route traffic system with real-time information

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ARTICLE INFO

Article history:
Received 25 April 2012
Received in revised form 11 June 2012
Available online 11 July 2012

Keywords:
Traffic dynamics
Signal control
Route choice
Complex system

ABSTRACT

We study the effect of signals on the vehicular traffic in the two-route system at the tour-time feedback strategy where the vehicles move ahead through a series of signals. The Nagel–Schreckenberg model is applied to the vehicular motion. The traffic signals are controlled by both cycle time and split. The tour times on two routes fluctuate periodically and alternately. The period increases with decreasing the split. Also, the tour time on each route varies with time by synchronizing with the density. The dependences of tour times and densities on both split and cycle time are clarified.

1. Introduction

Physics and other sciences meet at the frontier area of interdisciplinary research. Recently, transportation problems have attracted much attention in the field of physics [1–5]. The concepts and techniques of physics are being applied to such complex systems as transportation systems. The traffic flow, pedestrian flow, and bus-route problem have been studied from the point of view of statistical mechanics and nonlinear dynamics [6–15].

Mobility is nowadays one of the most significant ingredients of a modern society. In city traffic, vehicles are controlled by traffic lights (signals) to give priority for a road and to insure road safety because they are encountered at crossings. In real traffic, the vehicular traffic depends highly on the configuration and control strategy of signals. Brockfeld et al. have studied optimizing traffic lights for city traffic by using a CA traffic model [16]. Sasaki and Nagatani have investigated the traffic flow controlled by traffic lights on a single-lane roadway by using the optimal velocity model [17].

Until now, one has studied periodic traffic controlled by a few traffic lights [16,17]. Very recently, a few works have been done for the traffic of vehicles moving through an infinite series of traffic lights with the same interval. The effect of cycle time on vehicular traffic has been clarified [18–23]. The effect of irregularity of a signal's configuration on vehicular motion has been studied [24]. Lammer and Helbing have studied the effect of self-controlled signals on vehicular flow based on fluid-dynamic and many-particle simulations [25].

The influence of dynamic information on the traffic flow has been investigated using a route choice scenario [26]. The dynamics of traffic flow with real-time traffic information has been studied. The route-choice strategy has been investigated for the two-route, three-route, and crossing traffic systems using real-time traffic information [26–29]. In the two-route and three-route traffic systems studied until now, there are no traffic signals. However, city traffic is generally controlled by many signals. It is important and necessary not only to obtain real-time traffic information but also to know the control strategy of signals. The tour time on two routes with a series of signals has been studied for a low-density traffic without real-time information [30].

It is known that the vehicular traffic is affected highly by the configuration and control strategy of signals. The tour time and route choice depend highly on the signal's characteristics. The vehicular motion will vary not only with the route choice

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doi:10.1016/j.physa.2012.07.022

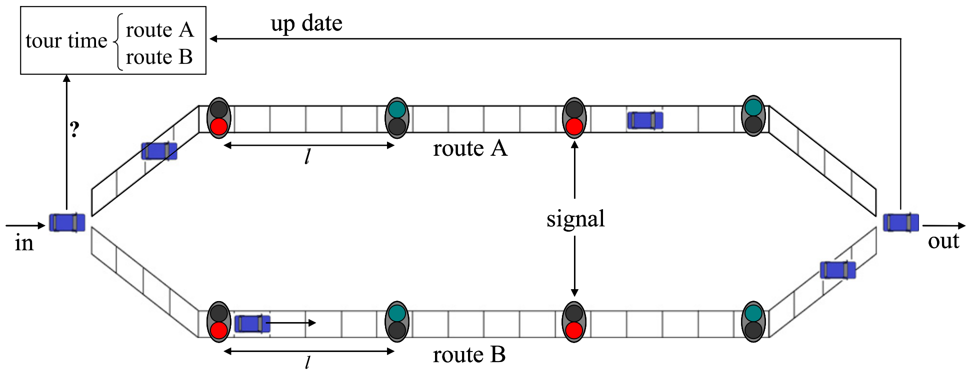

Fig. 1. Schematic illustration of the two-route traffic system at the tour-time feedback strategy. There are many signals on two routes with the same interval. Every time step, a road user enters the system and has to choose one route. After entering the route, the vehicle moves through the system according to the dynamics of the cellular automaton model proposed by Nagel and Schreckenberg (NS model).

but also with the signal's characteristic in the two-route traffic system using real-time traffic information. However, the route-choice problem using real-time traffic information for the two-route traffic system controlled by signals has been little studied until now. In the previous studies about the route choice, the drivers selected a non-congested route by using real-time information. There are no signals on the routes.

In this paper, we study the traffic behavior on a two-route system controlled by signals at the tour-time feedback strategy. We introduce the series of signals into the two-route traffic system. We investigate the dependence of the tour times and the densities on the signal characteristic by using the CA model. We clarify the effect of the signal's characteristic on the route choice.

2. Dynamic model and signal control

We consider the vehicular traffic through a series of signal on the two-route system at the tour-time feedback strategy. In order to demonstrate the effect of the feedback loop, the scenario with dynamic information is investigated. Fig. 1 shows the schematic illustration of the two-route traffic system with a series of signals. Suppose that there are two routes A and B with the same number of cells. Every time step, a road user enters the system and has to choose one route. After entering the route, the vehicle moves through the system according to the dynamics of the cellular automaton model proposed by Nagel and Schreckenberg (NS model). There are many signals on two routes with the same interval.

For convenience, the definition of the NS model is briefly reviewed for single-lane traffic. The road is subdivided into cells with a length. Each cell is either empty or occupied by only one vehicle with an integer velocity v_i where the maximum velocity is v_{max}. Let N be the total number of vehicles on a single route of length L. Then, the vehicular density is $\rho = N/L$. The motion of vehicles is described by the following rules (parallel update).

Rule 1. Acceleration: $v_i \leftarrow \min(v_i + 1, v_{max})$
Rule 2. Deceleration: $v_i' \leftarrow \min(v_i, gap)$
Rule 3. Randomization: with a certain probability p do $v_i'' \leftarrow \max(v_i' - 1, 0)$
Rule 4. Movement: $x_i \leftarrow x_i + v_i''$.

The variable *gap* denotes the number of empty cells in front of the vehicle at cell *i*. The maximum velocity is set as $v_{max} = 3$ throughout this paper. Also, the randomization probability is set as $p = 0.25$.

The traffic signals are positioned on two routes with the same interval l and are controlled by the following. All the signals change periodically with period t_s. Period t_s is called the cycle time. In the synchronized strategy, all the signals change simultaneously from red (green) to green (red) with a fixed time period $(1 - s_p)t_s(s_p t_s)$. The period of green is $s_p t_s$ and the period of red is $(1 - s_p)t_s$. The fraction s_p represents the split which indicates the ratio of green time to cycle time. We study the effect of signals on the two-route traffic system with the tour-time feedback at the synchronized strategy by varying both cycle time and split. The interval between signals is set as $l = 30$ throughout this paper.

If a vehicle arrives at a signal and the signal is red, the vehicle stops at the position of the signal. Then, when the signal changes from red to green, the vehicle goes ahead according to the movement of the NS model. On the other hand, when a vehicle arrives at a signal and the signal is green, the vehicle does not stop and goes ahead according to the movement of the NS model.

We review briefly the tour-time feedback strategy proposed by Wahle et al. [26]. Two types of vehicles are introduced: dynamic and static vehicles. A so-called dynamic driver will make a choice on the basis of the tour-time feedback, while a static driver enters a route at random ignoring any advice. The dynamic driver always chooses the route with the shortest tour time at the entrance. The densities of dynamic and static drivers are S_{dyn} and $1 - S_{dyn}$ respectively.

The simulations are performed in the following steps. First, we set two routes and an empty board (see Fig. 1). Second, after the vehicles enter the entrance, according to the tour-time feedback strategy, the tour-time information will be