The CSI Journal on
Computer Science and Engineering
Vol. 14, No. 1, 2016
Pages 29-37
Short Paper

A Novel Homogenous Bus Rapid Transit Model Using Hybrid Petri Nets

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Abstract

To better understand the characteristics of three connected vehicles traffic flows that are very common on a Bus Rapid Transit (BRT), in this paper a hybrid Petri-net based controller model be considered with different classical and new mobile stations bus will be proposed based on the information of three BRT buses. The bus moving model will consider in terms of the safe distance, speed, reaction time, and station setup time or delay. The experimental results of our model on different kinds of movement scenarios, show its impacts on significant improvement of distance and speed control with fast reaction time analyzing. These improve especially on mobile station with reduced delay and a good balance on station setup time. Traffic flow will be effectively increased up to 28% by changing classical stations to new mobile ones. This finding provides a possible way to ease traffic on the BRT network with three connected buses by different roles of BRT buses for passenger transport and BRT mobile station for passenger exchange.

Keywords: Bus Rapid Transit (BRT), Fluid Stochastic Petri-Net (FSPN), Mobil Bus Station (MBS), Bus Controller, Mobile Bus Rapid Transit (MBRT), Intelligent Transportation Systems (ITS).

1. Introduction

Recently, the continuous growth of motorization and urbanization around the world has rapidly lead to the increase of urban population and demand for automobile. Some various traffic problems such as congestion, accident and environmental impacts have become more serious in new, complicated metropolises. The building of more infrastructures and the presenting of new solutions such as Intelligent Transportation Systems (ITS) provide a better alternative to classic methods [6-7].

ITS technologies aim to equip the elements within transportation systems such as vehicles, roads, traffic lights, traffic signs and so on to improve the reliability and poverty of urban traffic. Also, it empowers these elements to communicate with each other for making better decisions and reducing its potential errors while enhancing safety and traveler satisfaction and convenience [4, 9].

1.1. Bus Rapid Transit System

Due to the nature of ITS, a large number of research topics in this area could be formulated as the problem for finding a better solution to optimal operation such as Bus Rapid Transit (BRT). Currently one of the most widespread public transportation systems, the BRT system is regarded as one of the best alternatives in terms of mass passenger displacement and has focused on the improving socio-economic dynamics of cities, rationalizing resources, especially as opposed to individual motorized forms [11]. Traffic congestion is an important condition in urban transport networks that occurs as use increases and is characterized by slower speeds, longer trip times, and increased vehicular queueing. The most common example is the physical use of roads by vehicles and their speed that lead to fully stopped or traffic snarl-up for periods of time.

Three homogenous BRT buses for the traffic flow of special lines is a very common and important subject for intelligent transportation systems for passengers' movement (see figure 1). All research has shown that although the number of BRT buses on special lines is relatively smaller than the number of cars, has a significant influence on traffic flow characteristics.

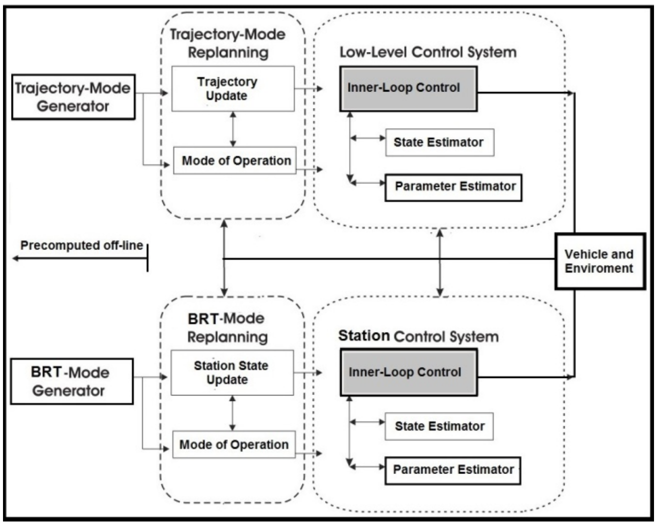

Figure1. Fully-Autonomous MBRT Guidance System

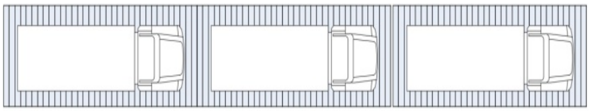

Figure 2. Three-connected MBRT Vehicles Model

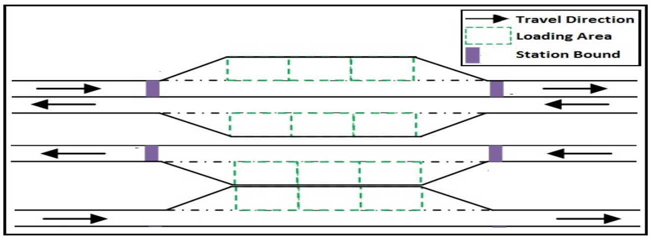

Figure 3. Classic Static Bus Station Model

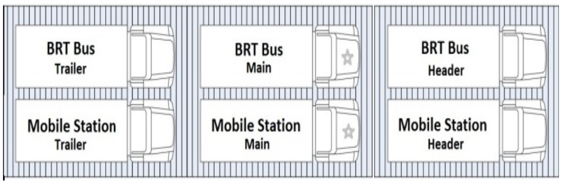

Figure 4. Schematic of New BRT Mobile Bus Station Model

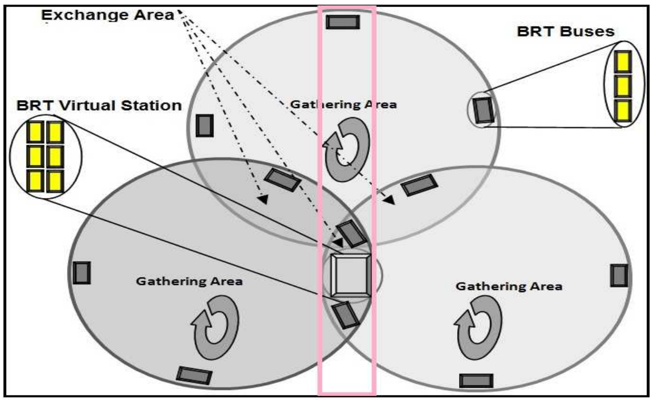

Figure 5. MBRT Virtual Network

Recently, the occurrence of major accidents on urban roads with human losses a new approach to traffic flow and BRT bus intelligence is needed [12]. Accidents have caused a large debate on how to increase road safety, reliability and intelligence especially concerning urban traffic which require and guarantee easy and fast flow [8].

One way to reduce urban traffic risk is to minimize undesired changes of traffic flow and speed by forcing BRT buses to respect speed limits, safety distances without any undesired lane changing. Car intelligence is a very important solution to reduce human risk on urban traffic flow. The control of three buses as a BRT model (see figure 2) is very difficult yet necessary to safe passenger movement in connected vehicles [13]. Designing a new bus controller for coordinating two or more BRT buses is a very difficult task that requires a better glance into traffic flow managing. This view needs a special road in crowded cities with safe buses and professional drivers. For the ITS program to reduce the impacts of human control risks, we must pay special attention when producing a novel bus with a special design of bus structure and bus station architecture. The program can construct special a controller to reduce the errors of the human driver by automation process analysis and design [12].

Traffic flow control needs to reduce some important delays for removing risk parameters of car controls on the urban environment [14]. BRT traffic flow is very dependent on bus station location of the classical static station. This requires a cost design of BRT equipment that removes any dynamic on reducing other risks. For an optimized solution of new cities, we need to design a flexible structure of BRT infrastructure with automatic control of the connected vehicles (see figure 3).

A novel dynamic bus station solution is an essential change in the classical design of BRT urban traffic. This virtual station helps us to redesign new ideas to transfer many important traffic risks for better risk management (see figure 4). The main objective of this paper is to model the scientific context of urban public transport management for applications focused on BRT systems, allowing the visualization of possible opportunities to increase the level and number of contributions to these systems.

1.2. BRT Controller System

This paper investigates a new modeling BRT bus controller with a novel mobile station. The model is based on intelligent BRT buses coordination synchronize to the new mobile station. This is done on fluid Petri nets (FPN) with a hybrid multilayer modeling approach [1]. Petri net is a formal method used for the specification and verification of concurrent and distributed systems [15]. The FPN model is used to represent a controller that keeps track of three consecutive buses to coordinate them with a similar structure such as the mobile station.

The controller controls its buses speeds and distances between them. It also, manages passenger transfer between BRT buses and the station. This issue warns of alarm or alert messages when the prescribed limits are violated. In this paper, it is shown that the FPN is a valid paradigm to model the dynamics of a BRT bus and mobile station in a detailed way.

1.3. Proposed BRT Model

The proposed Fluid Petri-based traffic method (FPNTM) occurs through some tasks as in figure 1. This is done to detect speed, distance values between buses' computation, distance threshold calculation, BRT parameter extraction, command generation of buses and between them, speed classification (SC), speed selection (SS) and station coordination. At first, this process is started by bus detection. Next, distance prediction task is done. Then, all measured values process to rank for speed classification. Finally, all ranked values are processed process by SC to select the best distance that is predicted by FPNTM. We use bus-based information for the network that proposes a stable speed predictor with low variance.

FPNTM is a control method that measures all relevant values based on its computations and its synchronization method with the bus information. This is done by clustering the BRT graph as three detected buses and speed prediction of all. SC calculations are computed based on the distance task result and the SS task result to select speeds to add to results. These calculations are very difficult and complicated on virtual bus location (any connected vehicles location) and based on our knowledge there is not any similar research on BRT modeling.

1.4. Mobile Station

We suppose that there is no static station in a BRT travel model. This reduces the travel cost and increases the performance. Next, we propose a new dynamic network of the BRT buses which gather passengers and exchange them without spending time or stopping at any physical station (see figure 5).

This will be carried out only with a virtual station in many locations on demand such as Mobile BRT (MBRT). This is a dynamic network for gathering and exchanging passengers in a dynamic area. The gathering and the exchanging areas will change their locations and dimensions on demand with predefined settings.

1.5. Motivation

In the realm of urban traffic much work has been done on exploring a single car safety model to prevent accidents on a road at a tunnel [18, 19, 29] and there are no works on three connected BRT vehicles to provide a better performance. Also, all related work is done without any view on mobile station cause low delay and capability in supporting different buses and stations. There is a lack of research that would enable the previos selection of a relevant mobile station to reduce the travel delay time according to the accentual correlation between buses and stations.

This needs a distributed parallel architecture and a suitable mobile station based on transportation looking at an automatic controller. Our paper addresses this problem, proposing a novel BRT model with a better controller to avoid any accident. We focus on the formal modeling of a novel controller for the special movement of the three connected buses to urban traffic.

1.6. Contributions

The main contribution of our work is that we look at "a novel BRT controller task model with a new mobile station" by applying the FPN model. We notice the correlation between buses and mobile stations to provide automatic selections. We look at a new Petri-net modeling to the secondary control of BRT by applying formal formulation to reduce the delay time and automatic generating alarms to prevent an irrelevant crash. Within this new paradigm, the driver will not need to discover peer bus with which to interact for the purposes of trade or cooperation. The key insight of our idea is selecting two different stationary and non-stationary (mobile) stations by evaluating them to prevent irrelevant crashes for reducing accidents of buses and passengers for automatic driver decision making. However, the controller is very helpful for driver guidance to a scalable high-cost BRT network; implementation of this controller is always difficult and has been identified as a potential weakness with respect to complexity. Its flexibly improves the accuracy and speeds the driver choices by allocating an appropriate agent to buses. Our contributions on modeling, awareness, and variation are summarized as below:

- **Modeling**: Formal modeling of a new FSPN controller of three connected homogeneous BRT vehicles and a novel BRT mobile-station.
- **Awareness**: Increasing BRT urban traffic flow with mobile stationary or mobile BRT bus stations with decreasing the station cost can delete the classical station.
- **Variation**: Presenting a dynamic network of the BRT system and low variance delay solution to a static station with a bit intelligent on driver guidance.

1.7. Paper Organization

The remainder of this paper is organized as follows. The related work is proposed in Section 2. Section 3 presents the description of some needed definitions and formulation of FPN model. The BRT formulated problem is explained in Section 4. Experimental results are provided and discussed in Section 5. Finally, Section 6 concludes the paper and mentions some future directions.

2. Related Work

Recent trends in the automotive vehicle has leaned in the direction of increased content of electronics, computers, and controls with emphasis on the improvement of the functionality of the system focusing on the structural integrity of (passive safety) vehicle and the avoidance of accidents for concurrent facilitating better vehicle controllability and stability especially in emergency situations of (active safety) vehicle [16]. Early works on active safety systems date back to the eighties and primarily focused on improving the longitudinal dynamics part of motion on effective braking, traction control systems and rejecting external destabilizing [17].

Selected attributes from the previous studies include: access time between residential location and BRT station, waiting time at a station, in-vehicle travel time of BRT, egress time between BRT station and destination, total travel time, and Ticket fare of BRT [21-24]. They did not work on the synchronization of some vehicle for active safety modeling on the BRT system to crash reduction as a part of the operating system for cars to report, monitor and act on different car events [18, 19, 29]. Many things have been done concerning the exploration of a single car safety model [3, 18, 19, 29] and there is no work concerning the the three connected vehicles of a BRT system to provide a better performance.

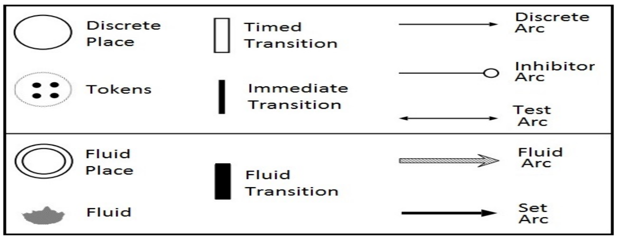

Figure 6. All Elements of FSPN [29]

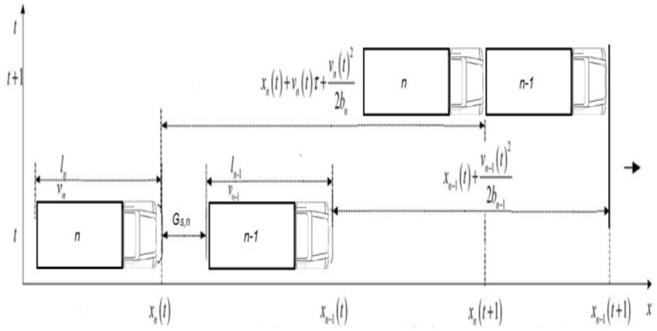

Figure 7. Safe Buses Distance Computation

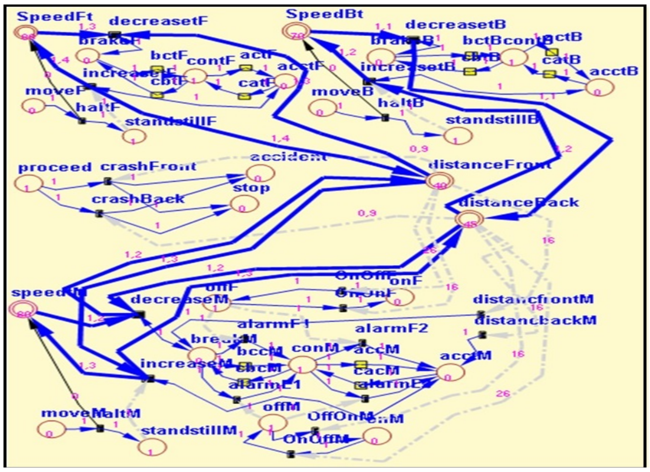

Figure 8. FSPN Model of Proposed Three-connected BRT Buses

We implemented the high-level operations of real-time controllers of three connected vehicles (as stations and movement connected buses) on a passenger BRT model, and performed tests on urban normal BRT roads to improve the functionality and reduce the delay of a short BRT trip for degrading some external and internal accidents of the subject. Based on our knowledge, this work is the first toaddress concurrent modeling and the control of two type of three connected busses to support high-level modeling and the function of a BRT system to improve the functionality and delay of a trip. This can reduce station cost and accident along with the trajectory planning system.

3. Fluid Stochastic Petri Nets

The Fluid Petri-net was proposed to model both nonstochastic [25] and stochastic [26] systems. We only propose a brief formulation of our needed formalism and more details are described in [27]. An FSPN model contains 3-tuple (place, transition, and arc) for discrete and continuous structures with a firing rule. A discrete place receives and transfers only a discrete number of tokens and a fluid place processes a continuous amount of fluid. Petri-Net marking is defined by the joint distribution of discrete and fluid (with fluid levels) tokens in discrete and fluid places.

We introduce a graphical model of all the primitive tyoes of FSPN in figure 6. According to the firing rule of immediate and timed transitions, discrete tokens are moved through the discrete arcs. Depending on the FPN marking, the firing times of timed transitions are processed by instantaneous firing rates. According to fluid rate, fluid place level is changed by fluid transitions. Also, it can be set depending on the marking of the net or directly on a given value of a set arc according to a transition firings. By a given number of tokens or a given quantity of fluid levels that are placed in a place, the inhibitor arcs (test arcs) can disable or enable a transition [29].

4. MBRT FSPN Model

We describe all needed definition and formulation for driving and controlling the BRT traffic modeling such as speed control, buses coordination and mobile stations' synchronization on passengers' transportation. We only propose the graphical presentation of our Petri-net system model (Figure 8) and ignore the complex formulation for an easy understanding of the MBRT.

4.1. BRT and Station Properties

We assume that all three original buses on a BRT model have a coordinator to control its speed and directions. This coordinator is placed on the middle bus of the three as the main Bus (MBus). The MBus can transfer its speed and other sensor information to another controller as the main Station (MStation). Also, the mobile station has a structure similar to the original with all needed sensors and controllers. These are the general three buses that can receive some signals to control their speed and an external system (from MBus). The mobile station bus is similar to the three BRT buses that control the Trailer, Main and Header buses with the same functionality (see figure 4). The Mbus and MStation are similar to the internal functionality and differ in external functionality. The external function of the MBus is to transfer data to the coordinate MStation with its operations. However, the received data is processed with the MStation to synchronize the station with its BRT system for passenger riding on and riding off the system.

4.2. Safe Distance Modeling

Safe distance is defined as the space that the bus must maintain to the preceding bus so as to avoid rear-end collision when the preceding bus brakes emergently. The safe distance is with respect to the braking ability of both the lag and preceding buses and the reaction time of the driver of the lag bus, as shown in figure 7. Thus, due to the different braking abilities of buses and the different drivers' reaction times for the four following combinations, the safe distances are different among the four following combinations as well. The safe distance is obtained by the four following combinations. According to the theory of calculating safe distance introduced in [28], the Eq.(1) is obtained.

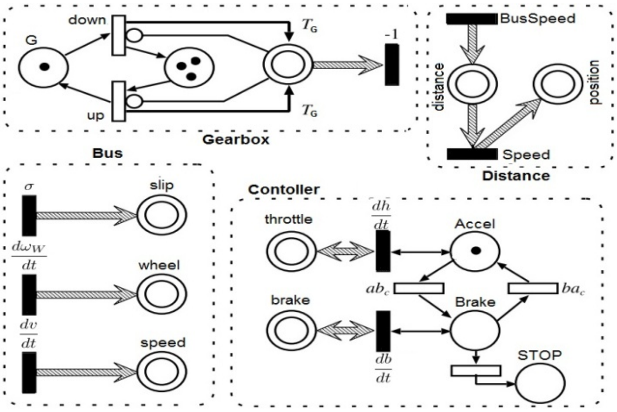

Figure 9. Petri-net Model of MBRT System [29]

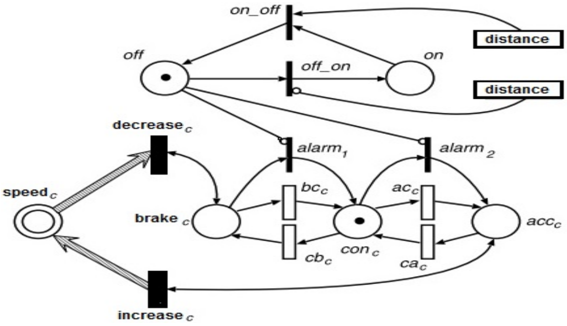

Figure 10. MBRT Main Bus Model [29]

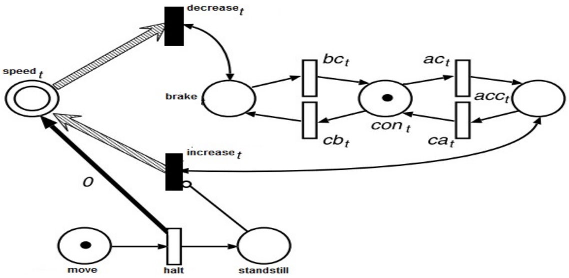

Figure 11. MBRT Front and Rear Buses Model [29]

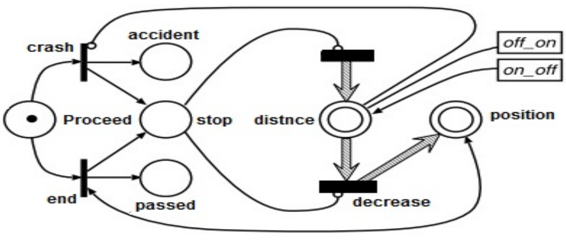

Figure 12. MBRT Distance and Position Model [29]

Rewriting Eq. (1) can acquire the expression of the safe distance that vehicle n has to main to vehicle $(n-1)$ in driving as (2). In this equation, $G_{s,n}$ denotes the safe distance of the n^{th} bus, $x_n(t)$ denotes the location of bus n at time t, $x_{n-1}(t)$ denotes the location of bus $n-1$ at time t, l_{n-1} is the length of bus $n-1$, b_n is the emergency braking deceleration of bus n, τ_n is the reaction time of the driver of bus n, $v_n(t)$ is the velocity of bus n at time t, and $v_{n-1}(t)$ is the velocity of bus $n-1$ at time t.

$$x_{n-1}(t)+\frac{v_{n-1}(t)^2}{2b_{n-1}}-l_{n-1}\geq x_{n-1}(t)+v_n(t)\tau_n+\frac{v_n(t)^2}{2b_n} \tag{1}$$

$$G_{s,n}=x_{n-1}(t)-x_n-l_{n-1}=v_n(t)\tau_n+\frac{v_n(t)^2}{2b_n}-\frac{v_{n-1}(t)^2}{2b_{n-1}} \tag{2}$$

$$\tau_n(t)\rightarrow\min\left(\tau_n(t)+\alpha_n, V_{max,n}, G_n\right) \tag{3}$$

$$\tau_n(t)\rightarrow\min(\tau_n(t), G_n) \tag{4}$$

$$\tau_n(t)\rightarrow\max\{\min(\tau_n(t), G_n-1), 0\} \tag{5}$$

$$\tau_n(t)\rightarrow\min(\tau_n(t), n) \tag{6}$$

For the different types of the following combination, τ_n has four alternatives,τ_{cc}, τ_{ct}, τ_{tc} and τ_{tt},whileb_n only has two alternatives, b_c and b_t. In moving, when the distance between the lag vehicle and the preceding vehicle is greater than the required safe distance, that is $G_n > G_{s,n}$, the vehicle n will accelerate according to (3). When the distance between the lag vehicle and the preceding vehicle equals to the required safe distance exactly, that is $G_n > G_{s,n}$, vehicle n will maintain the original velocity as (4). When the distance between the lag vehicle and the preceding vehicle is smaller than the required safe distance, that is $G_n < G_{s,n}$, vehicle n will slow down. There are two types of vehicle deceleration rules: if the preceding vehicle is stationary, for security reasons, safe deceleration rules will be used, that is the distance between the lag vehicle and the preceding vehicle is more than 0.85m; if the preceding vehicle is in a non-stationary state, i.e. $\tau_n(t)\neq 0$, the deterministic deceleration rule will be used and the safe deceleration formulation is as (5) and the deterministic deceleration is as (6).

4.3. MBRT Operations and Controller Model

To analyze the safe BRT controller, we model three buses (Trailer, Main, and Header in Figure 4) that follow each other in the BRT road based on [29]. All main elements (Gearbox, Distance, Bus and Controller) are presented in figure 9. To distinguish them, the main bus proceeding in the road will be called the Mbus while the one following in the front and rear are the HBus and TBus. The model that describes the behavior of the Mbus is depicted in figure 10. Three discrete places are used to distinguish the situations when the bus is braking (the place brake$_c$is marked), proceeding at a constant speed (place con$_c$), and accelerating (place acc$_c$). The token among these three places are moved by transitions bc$_c$, cb$_c$, ac$_c$ and ca$_c$. Different numeric values for the firing rates of these four transitions are assigned for different experiments and will be given in the next section based on FSPN rules [2]. The speed of this bus is represented by the level of fluid in place speed$_c$ which has a lower bound at zero (see figure 10).

The speed is decreasing (increasing) by transition decrease$_c$ (increase$_c$) when this transition is enabled, i.e.

when place $\mathrm{brake_c}$ is marked (place $\mathrm{acc_c}$ is marked and place standstill is not). Places move and standstill to get her when transition halt are added, in order to model a sudden stop of the bus due to a front collision with Mbus running in the opposite direction. When this happens the speed of the Mbus is set to 0 and cannot increase any more. The model representing the Fbus and Rbus are given in figure 11. The behavior of the two is similar to that of the Mbus. There are two differences. First, the sudden stop of these buses is not considered. Second, we model what happens when the alarm with which the bus is equipped sounds. Initially, the alarm is off(place off is marked). If the distance between the two buses is too small, transition off− on becoms enabled and the alarm turns on. Transition off− on is connected to fluid place distance (Figure 6) by an inhibitor arc, i.e. this transition is disabled until the distance is larger than a given limit.

The alarm turns off when transition on − off becomes enabled. This happens when the level of place distance is higher than a given limit since the transition on − off is connected by a test arc to the place distance. When the alarm is on, the bus immediately begins to the brake (since transitions $\mathrm{alarm_1}$ and $\mathrm{alarm_2}$ becom enabled) and keeps braking while the alarm is on. Figure 12 depicts the distance model representing the distance between the two buses and their position in the road. The distance between the two buses is represented by the level of fluid place distance. The level of this place is increased by the transition increase and decreased by the transition decrease. Transition increase pumps fluid to place distance according to the level of fluid place $\mathrm{speed_t}$, i.e. according to the speed of the bus. While transition decrease takes fluid away from place distance according to the speed of the bus, i.e. according to the level of fluid place $\mathrm{speed_c}$.

Table 1. Used Bus Model Parameters and Variables

Description	Parameters/Variables
Maximum Acceleration Force	$\mathrm{F_ACC}$
Maximum Braking Force	$\mathrm{F_BR}$
Bus Mass	$\mathrm{M_C}$
Air Drag Resistance Coefficient	$\mathrm{C_DR}$
Rolling Resistance Coefficient	$\mathrm{C_DR}$
Wheel Radius	$\gamma\mathrm{w}$
Gear Ratio	$\mathrm{x_g}$
Differential Ratio	$\mathrm{x_d}$
Engine Torque Function	$\mathrm{T_E}(\omega)$
Pacejka's Magic Formula	$\mathrm{f_p}(\delta)$
Inertia Moment of the Wheels	$\mathrm{I_\omega}$
Damping Constant	B
Throttle Position ($0 \leq h \leq 1$)	h
Break Position ($0 \leq b \leq 1$)	b
Bus Speed	v
Engine Angular Speed	omega
Wheel Angular Speed	omegaW
Longitudinal Slip	δ

Table 2. Setting Bus Model Parameters

Parameters	Value
Size (including the Standstill Distance)	18.2 m
Maximum Velocity	81 km/h
Emergency Braking Deceleration	$2.5\ \mathrm{m/s^2}$
General Acceleration	$2.1\ \mathrm{m/s^2}$
General Deceleration	$2.1\ \mathrm{m/s^2}$

The distance covered by the bus is represented by the level of fluid place position. The level of this place is increased according to the speed of the bus by transition $\mathrm{speed_c}$. Discrete place proceed is marked until the buses are in the road and no accident has happened. If the distance between the two buses becomes 0, the transition crash becomes enabled and the place accident becomes marked. Moreover, the system is stopped because a token is placed to place stop too. The level of fluid in place position provides the location where the accident happened in the road. If the bus leaves the intelligent road, transition end becomes enabled and a token is put in place passed which means that the two buses have passed the road.

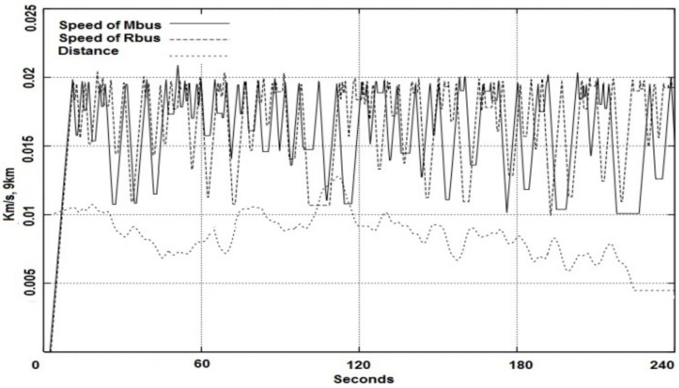

Figure 13. The Simulation Random Behavior Trace of BRT Buses

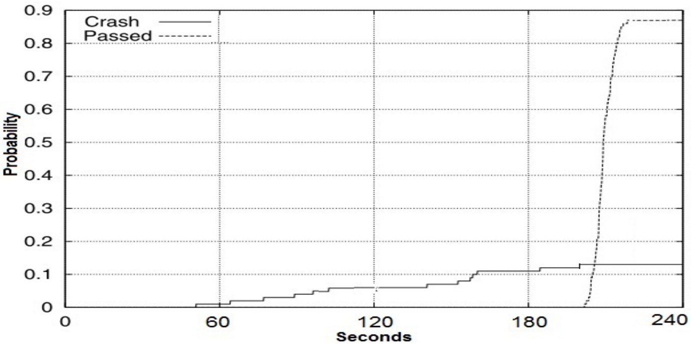

Figure 14. Accident and Passing Random Behavior of BRT Bus

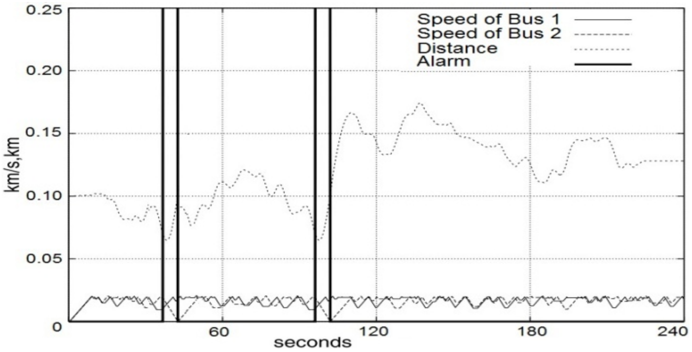

Figure 15. Driver and Alarms Behavior of BRT Buses

Table 3. BRT Trip Performance

BRT Buses	Static Station	Mobile Station
Average Delay Time (s)	534	384.5
Average Number of Stops	9.00	2.000
Average Stopped Delay (s)	6.20	1.800
Average Speed (km/h)	34.8	44.60
Average Trip Length (km)	15.7	15.80

5. Experimental Results

Our experiments aim to investigate the proposed FSPN BRT model. First, the experimented model is explained for system validation (Section 5.1). Second, we explain the used data set (Section 5.2). Third, we present the experimental setup and main results (Section 5.3).

5.1. System Validation

We check and validate the system and show that there is a one-to-one functional correspondence between the Petri-net model and the original requirements specification. For this, we use the Petri-net reachability tree which is extremely useful for the analysis of FPNs. The analysis involves the enumeration of all reachable markings or their coverable markings. The reachability tree represents the reachable states of a Petri-net from an initial marking. In the tree, every node represents markings generated and edge from one marking to another represents the transition fired. Moreover, it is shown that each new marking enables single transition and leads to single new marking. The specification model allows the bus to move forward on the road. In experiments to validate the system, we work to manually constructed data as test set [10]. We select some randomly generated data and a simulated real environment. Finally, we evaluate the system with the actual collected data.

5.2. Data Set

The used data in this study refers to the trajectory data collected at a southbound direction of the Iran BRT (Tehran's Enghelab Street). The entire segment is about 4.5Km in length, with two main lanes throughout the section and some auxiliary station sections. The entire data collection time period is 60min between 7:30 and 8:30a.m. during the morning peak hours. All the limits in the proposed model have explicit physical meaning, so we derive them directly from traffic observation. The specific parameter values of the buses will be shown in table 2 and the reaction time is 1.8s.

5.3. Experimental Setup and Result

The model described in Section 4 was analyzed by simulation under different assumptions. The following parameters were the same in all the experiments. Acceleration and braking change the speed of the vehicle according to a constant derivative. The buses accelerate from 0 to 100km/h in 10 seconds. When traveling at 100km/h, the buses need 100 meters to stop. Initially, the distance between the buses is 100 meters. Three buses start at speed 0. The BRT road is 30km long. To random behavior during the first experiment we assume that the BRT road is not equipped with an alarm (upper part of figure 13 is not present), a sudden stop of the bus is not considered or that the driver decides to brake, drives at a constant speed or accelerates in a completely random manner. In order to model random behavior, transitions bc_o, cb_o, ac_o and ca_o have exponential firing times with rate 1.0 (o stands either for t or c). A simulation traced with speeds of the buses and the distance between them is given in figure 13. Since we assume a random behavior the speed has high fluctuation. As a function of time the probability of a crash and of passing the BRT road is given in figure 14. As we go through the subsequent results we describe only what changes compared to the previous setting.

Reasonable drivers for the following experiments of the BRT road is equipped with an alarm. The alarm switches on when the distance between the buses is less than 3meters and switches offwhen it exceeds 5meters. Moreover, from now on, we assume that drivers are trying to maintain a predefined speed. This is done by defining firing rates for transitions bc_o, cb_o, ac_o and ca_o that depend on the actual speeds of the vehicle. These firing rates for both the buses are where $st = 70km/h$ $(sm = 40km/h)$ denotes the target (minimal) speed of the buses (see figure 15).

The simulation uses the periodic boundary and the road length equals to 70km. In the initial state we assume that $N = 3$ buses are on the road with uniform distribution, where the numbers of buses are N_c. Thus, the proportion of the buses is $P_t = N_c/N$. The average speed of bus traffic flow at time t is v(t) and $v(t) = \sum_{i=1}^{N} v_n(t)$. The simulation step is 1h. Each simulation realization is realized with more than 10,000s and we choose the last 1000s to present the simulation results. We ignore some undesired parameters such as bus capacity, the queueing system and so on. Finally, the results of the static and mobile stations on the system performance in a trip show a total of 28% improvement on delay time. This can reduce the cost of static station construction and change the BRT structure (see table 3).

6. Conclusion

We have proposed a novel robust BRT bus controller model using hybrid Petri-net with reasonable speed in urban traffic. Specifically, we use information of all three connected buses with the design a new mobile station to transport the BRT passengers. We have proposed an idea for a virtual location of each mobile station in the BRT network. Several experiments on a new and classical station model under different assumptions show that the behavior of our drivers and, in some circumstances, has better performance with better delay variance. The bus information has improved the accuracy and precision of our simulation.

These improve specially on added existence of mobile stations on a long urban BRT road. Future work might include uncertainty to our FSN approach in a multi-agent framework to achieve higher accuracy and speed in the control of automatic driving by studying their robustness. Further study on a real driver risky world for this evaluation would provide more insight. In addition, we will implement our method in a recommender driver system to make its recommendations more effective and applicable to an online BRT interactions environment.

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Paper Handling Data:

Submitted: 02.11.2016
Received in revised form: 10.12.2016
Accepted: 27.12.2016
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