ICIC Express Letters
Volume **13**, Number **1**, January **2019**

ICIC International ©2019 ISSN 1881-803X
pp. **19–25**

TRAFFIC VEHICULAR COMMUNICATION BASED ON PETRI NETS MODEL

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Received July 2018; accepted October 2018

Abstract. *Vehicular ad hoc network (VANET), a part of mobile ad hoc networks (MANETs), is a method capable for intelligent transportation system (ITS) which supports cooperative driving among vehicles on the road. Vehicle to vehicle communication (V2V) is a crash avoidance technology that relies on communication of information between nearby vehicles to warn drivers about potentially dangerous situations that could lead to crashes. Petri Net (PN) has come to play an important role in modeling and analysis. This paper proposes Petri Nets vehicular communication protocol (PNVC) for distributed vehicular broadcast packet using Colored Petri Net (CPN). The vehicle to vehicle communication protocol transmits broadcasting packet communication protocol between group of vehicles. We present a model for broadcasting packet communication protocol and emphasized on the process of simulating with Colored Petri Nets. Results of the proposed approach showed that CPN is effective in V2V communication, and it has suitable properties.*

Keywords: Petri Net, Vehicle to vehicle communication, Colored Petri Net, Intelligent transportation system

1. **Introduction.** Everyone needs to have a safe transportation that means with less human driving errors, the main cause of fatal accidents. Vehicle to vehicle communication is a promising technology to be used in accident avoidance by giving safety information to the system as well as to the driver [1]. Communication technologies open new management possibilities in the field of intelligent transportation systems [2].

The simplest scheme of broadcasting methods flooding can cause some problems such as high collisions redundancy and broadcast storm problem. Tseng et al. [3] discovered the broadcast storm problem and proposed several schemes to alleviate it. These schemes are specified for mobile ad hoc networks. Wisitpongphan et al. [4] designed three suppression techniques: weighted p-persistence, slotted 1-persistence, and slotted p-persistence. These schemes are very efficient at dealing with broadcast storm problems. Schwartz et al. [5] designed a dissemination protocol suitable for both sparse and dense vehicular networks and improved the slotted 1-persistence for their simple and robust dissemination protocol. Little et al. [6] proposed cluster-based schemes, and the network is divided

DOI: 10.24507/icicel.13.01.19

into many clusters. Cluster head is selected by calculating the variance of relative mobility of mobile nodes. The proposed approach will effectively address broadcast storm and network partition problems simultaneously by designing a novel Petri Nets vehicular communication protocol (PNVC) for distributed vehicular broadcast packet using Colored Petri Net. CPN provides a modeling framework suitable for simulating distributed and concurrent processes with both synchronous and asynchronous communication.

The rest of the paper is organized as follows. Section 2 presents definitions of PN and CPN related to the proposed method. We propose an algorithm to describe a vehicular communication model protocol based on Petri Net in Section 3. In Section 4, we show the simulation and results of our proposed model. Finally, Section 5 concludes this paper.

2. Concepts and Definitions.

2.1. **Petri Net.** Petri Net is a graphical and mathematical modeling tool for the design and analysis of discrete event dynamic systems (DEDSs) [7,8] and hybrid systems [9,10].

2.2. **Colored Petri Nets.** A CPN is a modeling language for systems where synchronization, communication and resource sharing are important [11]. CPNs are extensions of Petri Nets using different categories of tokens called colors and these values are manipulated in transitions. The development of CPNs was introduced by Kurt Jensen in 1980 [12]. The application areas of CPNs are communications, automated production control systems, distributed systems and work flow management analysis. CPNs lead to compact net models by using the concept of colors.

A Colored Petri Net is a tuple (Σ, P, T, A, N, C, G, E, I) where [13,14]:

- Σ is a finite set of non-empty types, also called color sets.
- P is a finite set of places.
- T is a finite set of transitions.
- A is a finite set of arcs such that: $P \cap T = P \cap A = T \cap A = \emptyset$.
- N is a node function. It is defined from A into $P \times T \cup T \times P$.
- C is a color function. It is defined from P into Σ.
- G is a guard function. It is defined from T into expressions such that: $\forall t \in T$: [Type (G(t)) = B   Type(Var(G(t))) $\subseteq \Sigma$].
- E is an arc expression function. It is defined from A into expressions such that: $\forall a \in A$: [Type(E(a)) = C(p)MS   Type (Var(E(a))) $\subseteq \Sigma$] where p is the place of N(a).
- I is an initialization function. It is defined from P into closed expressions such that: $\forall p \in P$: [Type(I(p)) = $C(p)_{MS}$].

3. **Proposed Petri Nets Vehicular Communication Protocol (PNVC).** In urban, each vehicle on the traffic is required to periodically to broadcast its BSM packets which include the vehicle position, speed, moving direction, and other vehicle control information at a frequency of 10Hz [15]. The current driving condition in real time recognized by beacon responds quickly to dangerous situations to avoid an accident [16]. This technique aims to assign vehicles to different transmission packets that are inversely proportional to their distance to the sender. In the typical scenario illustrated in Figure 1, the vehicles' movements in a highway environment are linear. These movements are constrained by the road topology which is divided into different slots that include different vehicles. Broadcast is a process to send the same message from a source node into all nodes in the network.

Our model assumes that each vehicle is equipped with a device capable of obtaining the current vehicle's geographical position, such as a GPS receiver and it is also based on the assumption that each one-hop is divided into four small fixed areas, denoted by t called the time slot. The time slots match regions within the transmission range of the sender, and every vehicle is assigned to different time slots depending on their distance to the

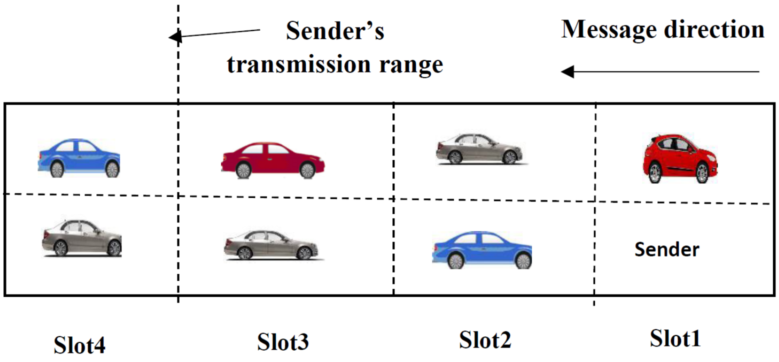

FIGURE 1. Different vehicles in time slots

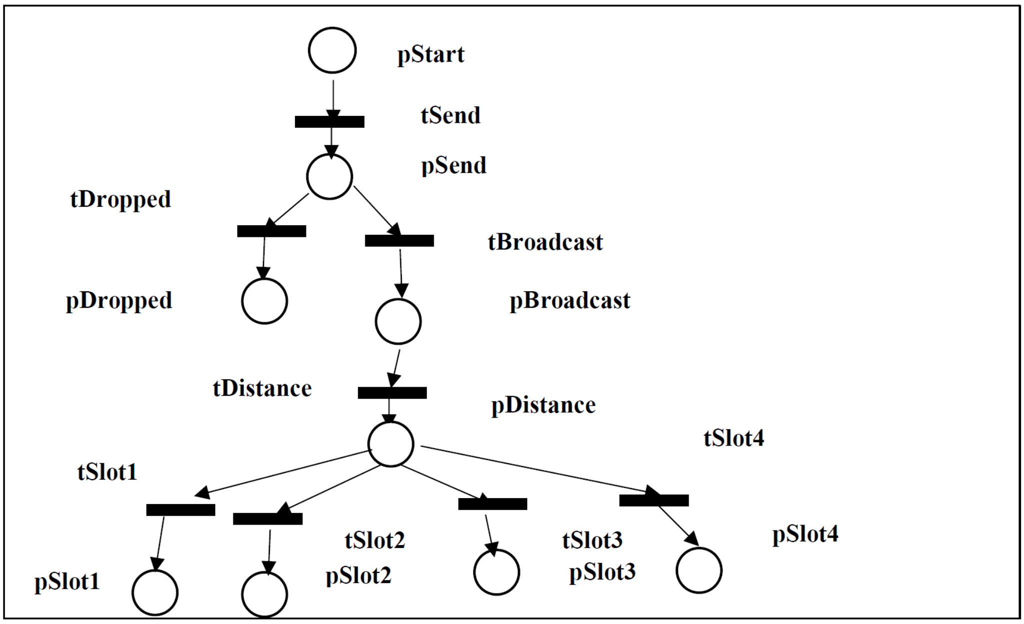

FIGURE 2. Broadcast packet communication using Colored Petri Net

sender. The vehicle may be located within the transmission ranges of many neighboring vehicles. The broadcast message format is: Vehicle ID, Message ID, Time Stamp and Vehicle's Geographical Coordinates.

Our designed model sends the packets from the source vehicle and ignores the confirmation packets from the receiver vehicles. CPN model is illustrated in Figure 2 and the following algorithm of broadcast packet.

Algorithm: Distributed Vehicular Broadcast Packet Using Colored Petri Net

1. The sender vehicle sends beacon message with rates packet per second, transition tSend is fired.
2. When sender vehicle sends packet successfully, transition tBroadcast is fired. Otherwise, packet dropped, transition tDropped is fired.
3. Calculate the distance between vehicle in range of sender vehicle, transition tDistance is fired.
4. If distance less than 50 unit, transition tSlot1 is fired.
5. If distance between (50-99) unit, transition tSlot2 is fired.
6. If distance between (100-150) unit, transition tSlot3 is fired.
7. If distance more than 150, the vehicles out of range the sender vehicle transition tSlot4 is fired.

Table 1. Description of the transitions in the broadcast model

Transition	Description
tSend	The source vehicle sends a message
tBroadcast	The transition will be fired if packet successfully broadcast
tDropped	The transition will be fired if packet dropped
tDistance	Calculate the distance between vehicles in range of sender vehicle
tSlot1	The transition will be fired if packet assigned into time slot1
tSlot2	The transition will be fired if packet assigned into time slot2
tSlot3	The transition will be fired if packet assigned into time slot3
tSlot4	The transition will be fired if packet assigned into time slot4

Table 2. Description of the places in the broadcast model

Place	Description
pStart	Initial state
pSend	Represents the content of the sending packets to other vehicles
pBroadcast	This state represents receiving a packet from a source vehicle
pDropped	Storage packet dropped
pDistance	Store the packet
pSlot1	Vehicles in Slot1 save the packet
pSlot2	Vehicles in Slot2 save the packet
pSlot3	Vehicles in Slot3 save the packet
pSlot4	Storage packet in Slot4

The role of places and transitions are shown in Table 1 and Table 2. The place ‘pStart’ used to generate the first message and the initial number of token is 1. This place is without color. The place ‘pSend’ represents the content of the sending packets which are indicated by ‘B’ and ‘D’. ‘B’ stands for the broadcast packets, while ‘D’ stands for dropped packets. The place ‘pDropped’ is used for the storage packet dropped. The place ‘pBroadcast’ represents receiving a packet from a source vehicle. The place ‘pDistance’ represents storage of the packet. The place ‘pSlot1’ is used to store packet in Slot1. The place ‘pSlot2’ is used to store packet in Slot2. The place ‘pSlot3’ is used to store packet in Slolt3. The place ‘pSlot4’ is used to store packet in Slot4 which means out of range of source vehicle. The transition ‘tSend’ fired which means the source vehicle sends a message. The transition ‘tBroadcast’ fired which means packet successfully broadcast from source vehicle to all vehicles nearby it. The transition ‘tDropped’ fired will tell us that packet will be dropped. The transition ‘tDistance’ fired which means to calculate the distance between vehicles in range of sender vehicle and then it adds colors to the tokens. The transition ‘tSlot1’ fired which means the packet receives in vehicles with distance less than 50 unit. The transition ‘tSlot2’ fired which means the packet receives in vehicles with distance between 50 and 99 unit. The transition ‘tSlot3’ fired which means the packet receives in vehicles with distance between 100 and 150 unit. The transition ‘tSlot4’ fired which means the packet does not receive because the vehicles in distance are more than 150 unit.

4. **The Simulation and Result.** The model designed by this work uses Colored Petri Net in the broadcast packet communication. GPenSIM toolbox is used for building the Petri Nets. It works in the Matlab environment and is very powerful. It can also integrate with the available Matlab toolboxes.

We divided our CPN model into two parts which are depicted in Figure 3. As illustrated in Figure 3(a), the system starts when the source vehicle sends a message, and transition 'tSend' is fired. If transition 'tBroadcast' is fired, it means packet broadcast successfully otherwise if transition 'tDropped' it means packet dropped. If the packet is broadcast, the model will go to the 'pBroadcast' which means that the packet receives from a source vehicle (See Figure 3(b)). Finally, in Figure 3(c), when the model calculates the distance between vehicles in range of sender vehicle, transition 'tDistance' is fired. If distance is less than 50 unit, transition 'tSlot1' is fired. If distance between (50-99) unit, transition 'tSlot2' is fired, if distance is between (100-150) unit, transition 'tSlot3' is fired, otherwise if distance more than 150 unit, transition 'tSlot4' is fired. Figure 4 shows the change of the broadcast rate and the percentage of successful packets broadcast and dropped packets rate, in which the horizontal axis stands for time and the vertical axis stands for percentage. The blue curve shows the changing percentage of the successful packets broadcast in all the broadcast packets. The yellow curve shows the changing percentage of the dropped packets in all the packets. According to the result of the simulation we can know that after 100 unit, time 98 packets are sent, including 74 broadcast packets in which 25 of them are dropped. The dropped packets accuracy rate is 0.34.

Each line of the data represents the status of the Petri Net after one more broadcast packet is detected in broadcast coverage that assigned time slot. The data following 'time' is the running time of the model.

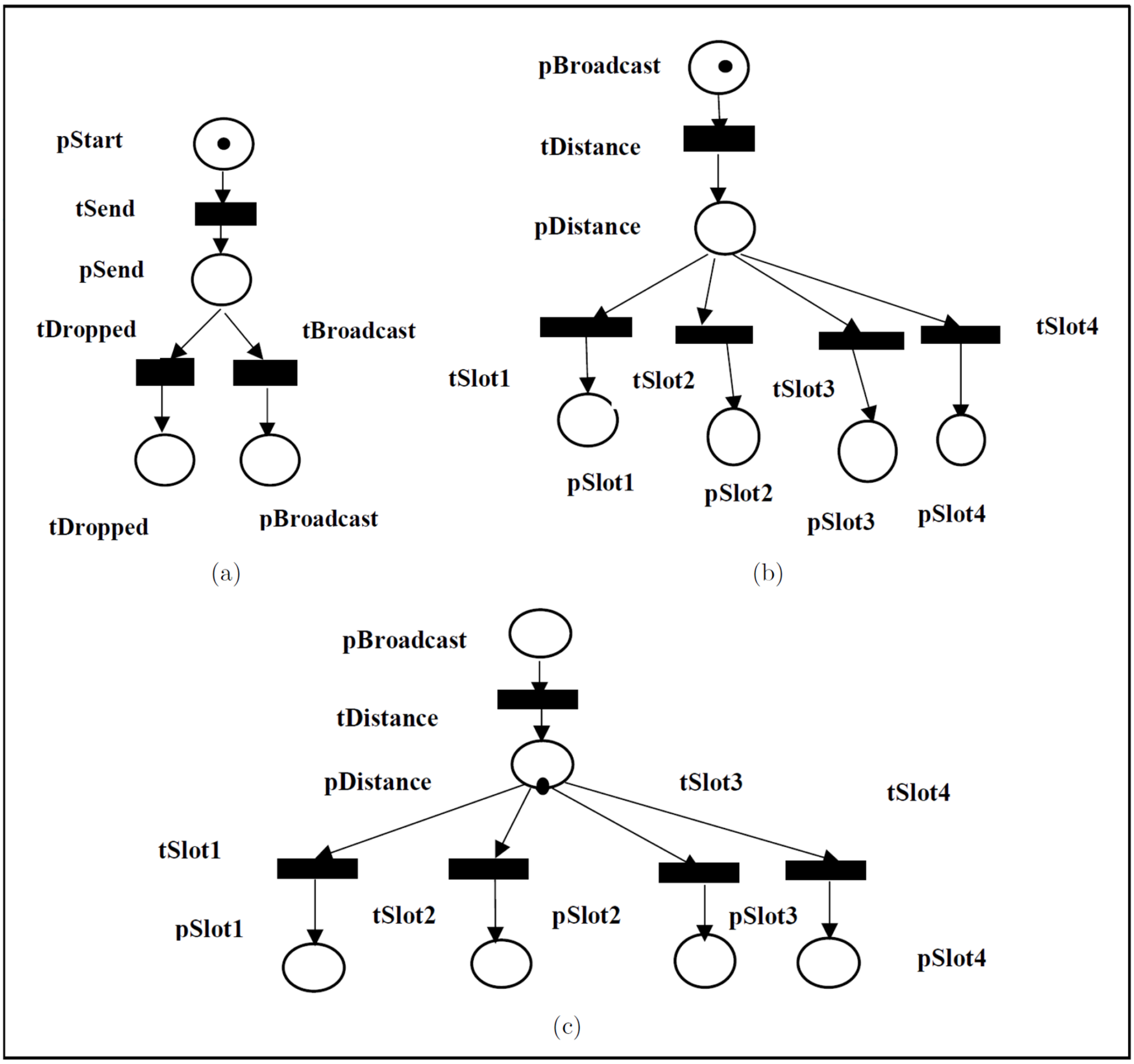

Figure 3. The steps of broadcast packet between group of vehicles

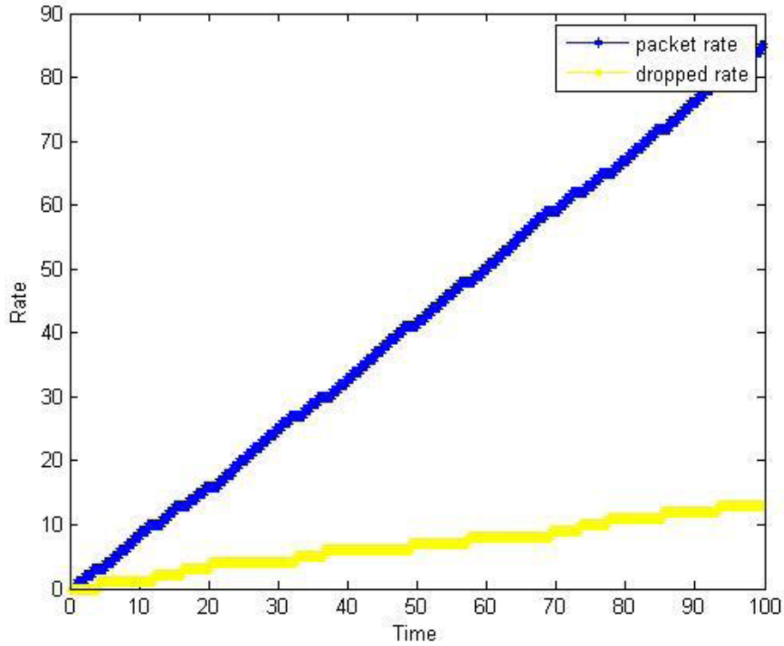

FIGURE 4. The curve chart for broadcast packet simulation

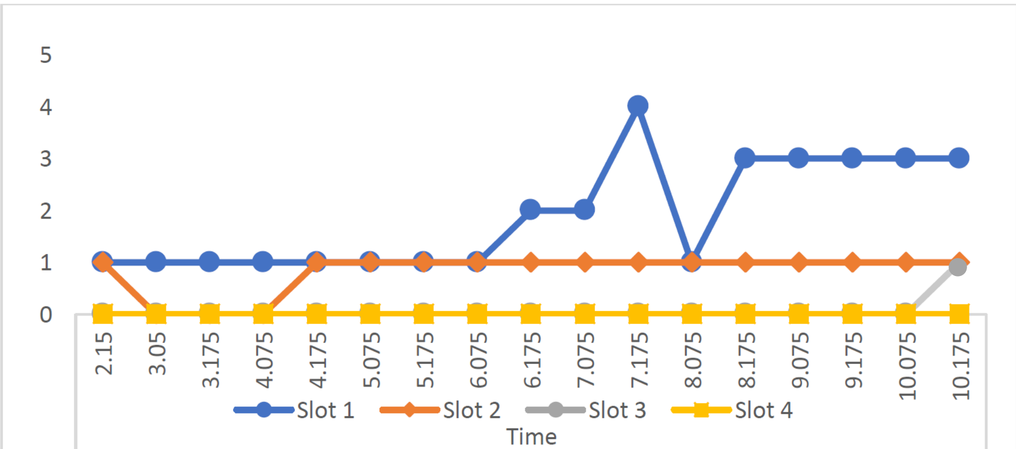

FIGURE 5. The result of broadcast packet in time slots

In Figure 5, the blue curve shows the changing percentage of the broadcast packets in time slot1. The orange curve shows the changing percentage of the broadcast packets in time slot2. The silver curve shows the changing percentage of the broadcast packets in time slot3 and the yellow curve shows the changing percentage of the broadcast packets in time slot4. According to the result of the simulation we can know that after 100 unit time the packets transmission ratio in slot1 is 58%, the packets transmission ratio in slot2 is 41%, the packets transmission ratio in slot3 is 25%, and finally, the packets transmission ratio in slot4 is 0%.

5. **Conclusion and Future Work.** Traffic accidents are one of the main health risk problems because the number of vehicles on the road increases so does the number of fatalities and injuries. This paper presents Petri Net vehicular communication protocol method to transmit broadcast packet communication between group of vehicles. The protocol of broadcast packet communication using Colored Petri Net is referring to our analytical and simulation results, and it can be noticed that the decrease of distance between source vehicle and other vehicle in time slots the result is incremented of successful

packets. In future work, we will extend this analysis by using V2V data under different weather conditions in the road traffic platform.

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