IJCSE International Journal of Computer Sciences and Engineering **Open Access**

Review Paper **Volume-5, Issue-12** **E-ISSN: 2347-2693**

A Petri-Net Based Representation of Automated Railway Signalling System with Collision Avoidance

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Available online at: www.ijcseonline.org

Received: 02/Nov/2017, Revised: 19/Nov/2017, Accepted: 10/Dec/2017, Published: 31/Dec/2017

***Abstract*—** In today's fast going life railway plays a major role as a public transport in different countries. And it's a very difficult job to control the railway traffic signal manually considering all kinds of situation and also it is very difficult to find out whether any deadlock situation has occurred or not. This work is emphasized on use of Petri nets in modeling railway network as well as railway signalling system and designing appropriate control logic for it to avoid collision. Here, the whole railway network is presented as a combination of the elementary models – tracks, stations and points (switch) within the station including sensors and semaphores. We use generalized mutual exclusion constraints and constraints containing the firing vector to ensure safeness of the railway network. In this research work, we have actually introduced constraints at the points within the station. These constraints ensure that when a track is occupied, we control the switch so that another train will not enter into the same track and thus avoid collision.

***Keywords*—** Petri nets, safeness constraints, firing vectors, asynchronous systems.

I. INTRODUCTION

Whenever a model of a Complex system comes into picture, understanding of that model is very important .For that reasons we need some tools that specify system very clearly. In sense clearly means, it would be capable to specify all the aspect of problems, and all solutions of it. It will describe entire system in such a way that it is easy to understand.

Automatic Railway Signalling System is a complex system. It has much functionality. As the system gets many types of input set, it will behave, and gives output. For that reason system should specify all the aspect of behavioral details (Workflow) as well as response for each type input.

Now we are using Petri net diagram to specify this system.
To simplify this we are dividing the entire signaling system into three basic parts. Those are 1) Normal-Line-Section 2) Junction-Section 3) Terminal-Section. We are considering those three as individual system.

Each system takes a predefined input and behaves as it gets and gives output as well. Depends upon those output once again system takes input and behaves as per.

II. PETRI NET BASICS

Petri Net is a formalism used for modeling and analysis of systems with concurrent processes and their behavior. As the authors in mention, Petri Net can be considered as a model of a system with concurrency that has graphical notation, precise mathematical language and analysis methods for specifying of the system behavior.

In the most basic form, it consists of places, transitions, arcs and tokens that are placed into a graph. Places and transitions are two types of nodes of the graph. Oriented arcs connect places with transitions and vice versa, while no pair of nodes of the same type can be connected. Tokens are in the places.
Now Place is basically denotes the state of a system. It is draw as a circle. Arc is defined connections between two or more than two system. Tokens are there to define which system is active and which is inactive.

Adding and removing of tokens to and from places represents the dynamic behavior of the net. It happens when a transition, to which the places are connected, fires, i.e. removes and adds appropriate tokens based on the conditions set by oriented arcs.
Each place is connected to the transition bar and vice-versa.

Actually case of adding and deleting token from the place happens a transition bar, connected to place and from a place is triggered.

Just like below pic-1.1 is shown

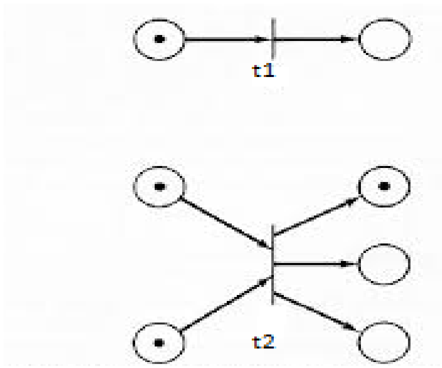

Figure 1: Basic Petrinet Diagram

III. PRINCIPAL ASPECT IN MODELING WITH PETRI NETS

As mentioned above, Petri Net models (the P/T Petri Nets) contain 4 types of basic elements that can be assigned to real elements depending on the expected goals.

For instance, in a model of car traffic in a road transportation system, one vehicle can be represented as a token that moves in the net between different places and transitions symbolize network of routes. In another model, describing different speed levels of an automobile, the same vehicle can be represented as a set of places, where one place means a certain speed level of the vehicle. In this model, token moving between places through transitions would mean different current speed of the vehicle.

It can be seen that after developing the first model, we can hardly use anything from it in developing the other one. So the other model has to be started from the beginning. If we wish to combine both approaches in one model, we'll probably have to choose another modeling paradigm.

Major goals to be achieved by creation of Petri Net models are usually:

- Description of the real system,
- Simulation of behavior of the real system with modeling of different situations of the system, that are sometimes even difficult to achieve in real system,
- Analysis of the system behavior to find a deadlock or
- Statistical results about the system behavior.

IV. CURRENT RAILWAY SIGNALING SYSTEM

In the current days railway has been using Interlocking System and Manual Control for Traffic and Signaling. In this case a Controller has to manually assign a track for a train. Once it gets assigned then it is not possible to assign that particular track for another train on that time. Signal for this always would be red. But controller must have to keep track which track is going to get assigned, and always have to send the update report to another controller.

A minimal interlocking consists of signals, but usually includes additional appliances such a point (US: switches) and derails, and may include crossings at grade and movable bridges. Some of the fundamental principles of interlocking include:

- Signals may not be operated to permit conflicting train movements to take place at the same time.
- Switches and other appliances in the route must be properly 'set' (in position) before a signal may allow train movements to enter that route.
- Once a route is set and a train is given a signal to proceed over that route, all switches and other movable appliances in the route are locked in position until either the train passes out of the portion of the route affected, or the signal to proceed is withdrawn and sufficient time has passed to ensure that a train approaching that route has had opportunity to come to a stop before passing the signal.

Figure 2: Current Signalling System

Now the thing is it fully hardware controlled system. Controller always has to keep track which track gets assigned and which track is not. If a trains running with delay then this is very hard for controller to assign its desired track, because it may happen on that there is another train for that particular track. Controller always has updated the train report for next controller. But sometimes it calls some dangerous accident. It is not always possible to keep track all train's signal and change as per. It requires a huge man-power, communicational-medium (Controller-to-Controller, Controller-Stationmaster). As well as it requires huge electronic switches and power knob to manipulates the signal. 45% of train accident in India happens due to signaling error. Sometime this manual system is the reason of delay of trains. In case large terminal station e.g. Chennai Central, Sealdah Terminal, Howrah station, traffic of those stations are huge. To directed a train to its desired line, on its scheduled time is a challenge for controllers and risky as well. In this driver's of those has to alert about the junction point and signal.

V. AUTOMATIC RAILWAY SIGNALING SYSTEM USING PETRI-NET

Here in this situation we are incorporating an idea of automatic signalling system. Basically system will working with input of sensors. Sensors are installed into the track. When a train came across the those sensor, it will fetch the unique information of that particular train and send it to the database, querying all information of that train, according to its destination, track will be switched and signal made.

Now we design entire system using petrinet graph. It shows all the behaviour of the system depending upon the inputs,(In real life inputs are retrieved from the sensor. Basically Entire system has been divided into three parts.

1. Normal line section
2. Junction Section
3. Terminal Section

1) Normal-Line Section

In case normal line section entire route is divided into some block. When a train enters in a block first sensor fetched unique id of this train, send to the database. Then program retrieve all information about of that train and check the previous sensor state. Depending upon the status of next sensor's data signal will made. Each block has a database that will store information of every train passing through this block.

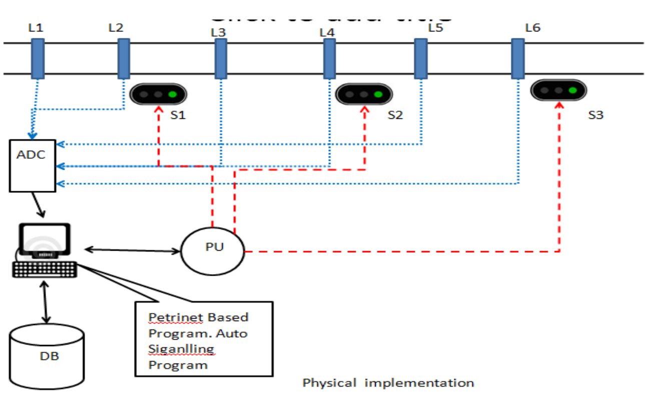

Figure 3 : Normal Line Section System

Petrinet diagram of this would be like that

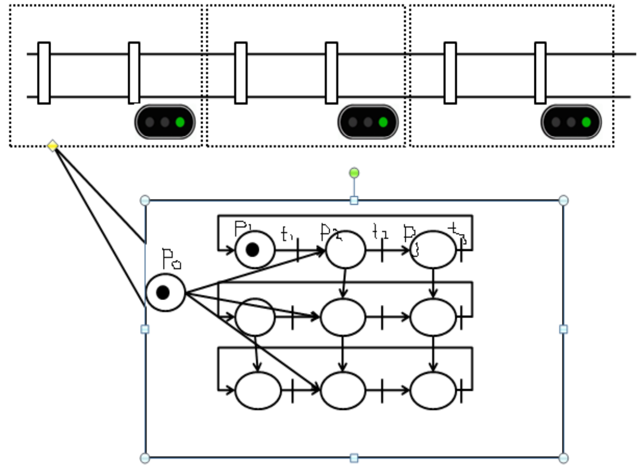

Figure 4 : Petrinet Diagram of Normal Line Section

Here P_0 place indicate the train that recently enter into the block. So it has a token, means Active (Ready to go).

P_1--> place indicate the clearance after, system has got all information about that train from Database.

P_2--> indicates action of driver after getting the signal.

P_3--> indicates final action of driver.

Now this entire thing is repeated when it enters into another signal block. Upper three connected places are indicating the state if driver get GREEN signal, Middle three connected place indicate the yellow signal, and lower three places are indicates Red signal. But these layers are connected to each other. Suppose after getting one green signal it may happen that next signal is yellow then should be passed to the Middle layer and proceed. After reaching P_3 place weather it passed to the P_1 or underneath place of P_3.

After getting input as sensor's data token can be transferred in any place, and system will show its behaviour as per that. Here Controller need not set the signal for any train. He/She will get notification as the any train come through his area of control.

2) Junction-Section

In junction section not only signal has to set but also track-point has to set to its desirable direction. Here we consider two line of junction. Sensors are installed in each line. It will send the information about train from database so that our program can set signal and track point. When two trains comes at same time from two lines, and then system will check and compare their priority. Higher priority train gets clearance first then lower priority train.

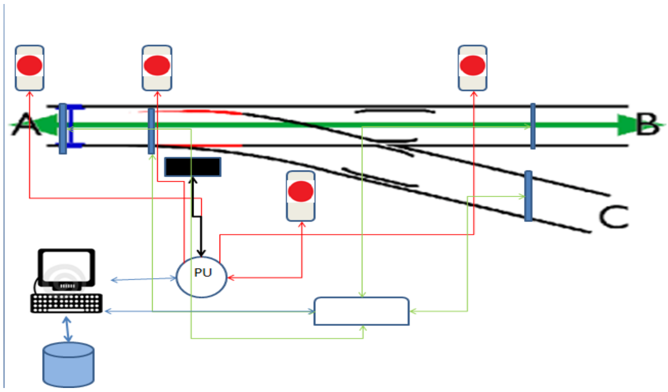

Figure 5 : Junction Line Section System

Information of trains passed through this junction is loaded to the database. Now whenever a train sends it's id from sensor according to its information saved into database system will perform operation

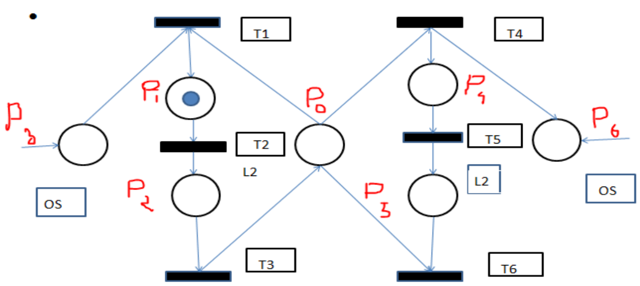

Figure 6 : Petrinet Diagram of Junction-line

Middle place P_0 has a token, both side of those indicating main line and loop line. If P_3 has got a token that means a train is in main line wants to cross junction section. So T_1 fired, token passed to the P_1(that means track point is set) then T_2 has fired token placed to the P_2(that means Signal set for that train) after that T_3 fired token once again set to P_0, means junction section is now in ideal mode. Now (P_6-> P_4-> P_3) if token serve from loop section then same thing is happen.
But there is critical case, if P_1, P_0, P_3 three place has the token at same time then T_1 and T_2 simultaneously enable to fire.

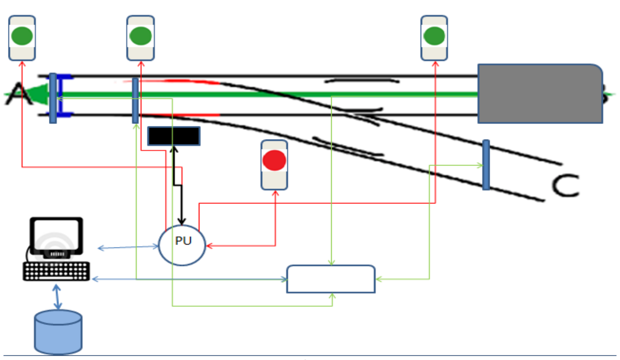

Figure 7 : Diagram of passing through main track

When a train is in main track, all information about that train will retrieve from database and signal is made for this train.

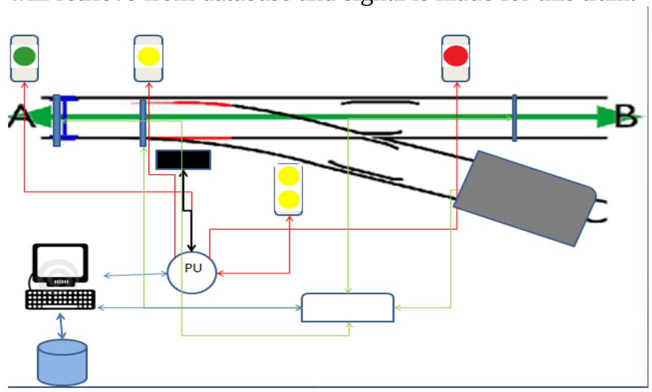

Figure 8 : Diagram of passing through loop track

When train is in loop track then also same thing is happen. Point track is set and then signal made.
In this way Junction point could be automated.

3) Terminal-Section
Last point is Terminal section where many Platforms and junction point exist. However we have automated the junction point but platform entering and leaving sequence should automate and platform assigning program should be automated.

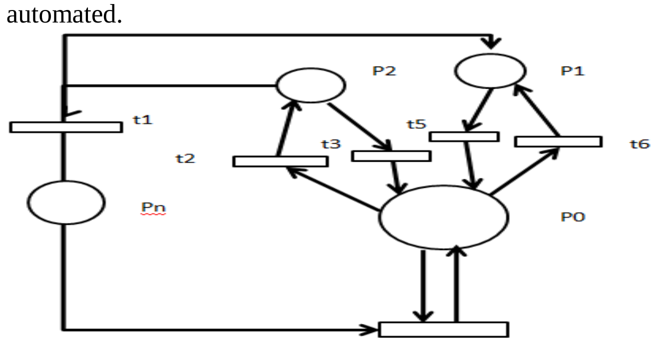

Figure 9 : Petrinet Diagram of Normal Line Section

So now P_0 is indicating as Junction point of this terminal. In this place to token is available for two platform (that is P_1 and P_2) when a train comes to the platform no. 1 means place P_1 in this diagram, for that case P_1 is locked, no other train will occupy this place until and unless the train gets depart. In this token pass to those places from P_0 place if all the platform is occupied then t_1 can be able to fire that. That means if a trains comes, it not find any empty platform then, it will send to the reserve track. After certain time train gets depart from platform and tokens are sent to the P_0 place. In this way we can automate the entire terminal signals. This will reduce delay, increase the frequency of trains. Collision of train can be prevented.

VI. INTEGRATION OF ENTIRE SYSTEM

Now we have discussed three basic section of railway and workflow of those. But in real life those models should integrated and work simultaneously. We are considering, in this integrated model 2 terminal station, 1 junction; rest of area is occupied by normal line section.

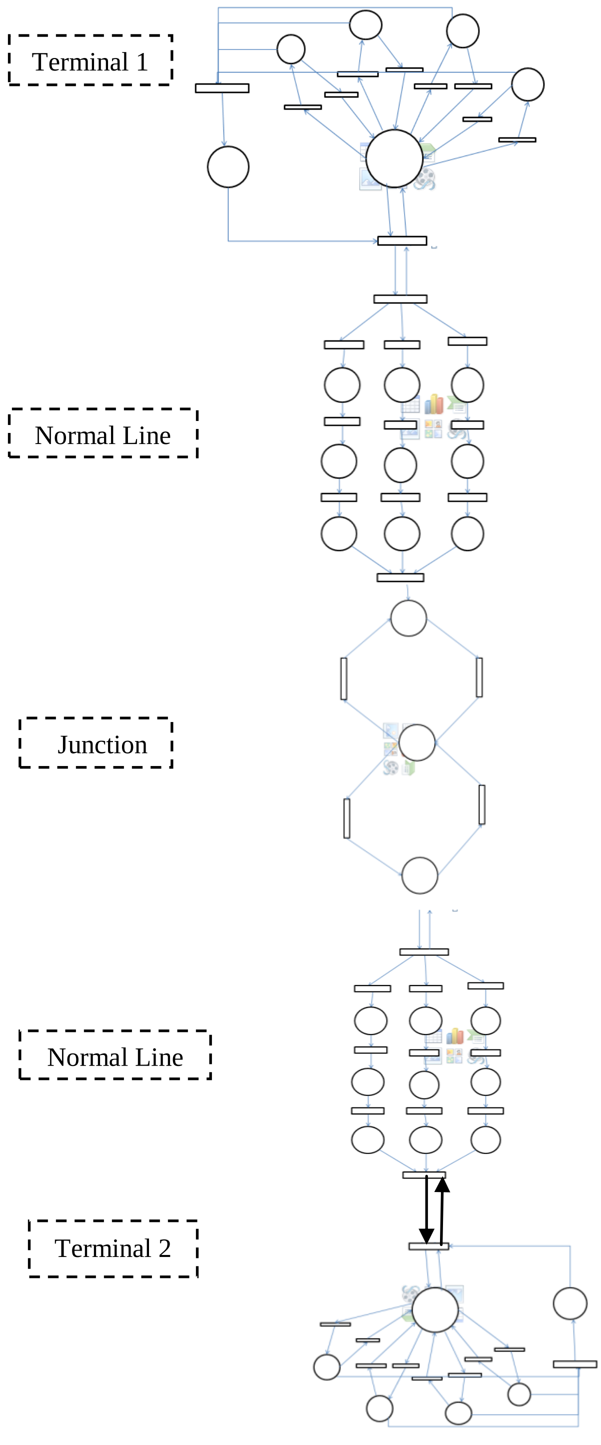

Figure 10 : Petrinet Diagram of Entire System

Above diagram indicates a signalling system. It is started from a Terminal station then come across the Normal line section then entering to the Junction Section after that once again enter normal line section and ends with Terminal section. We are assuming that both terminal stations have 4 platforms.

VII. CONCLUSION

Dealing with Train traffic control is so time consuming and complex that large traffic require multiple crewmen. With the new Signalling control system, the distribution of controller workload will shift away from monitoring the separations of all train in a sector and move toward the management of traffic flow and handling those exceptional problems that only human beings have the knowledge and skill to solve.

In this work, we explain the current train signalling control system and the problem it is facing. Petri net models are used to construct the discrete event models for station, junction and terminal systems and point locking control systems. The former can provide interlocking system and manual configuration for arrival and departure. The later works on any railway signaling system to give a safe and less time consuming output.

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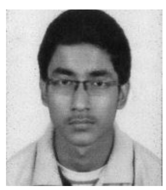

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