International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

Petri Net Based Design of Auto-Signaling Framework in Railway Network

Suparna Karmakar[1] Trishita Ghosh[2] Moumita Das[3] Chowdhury Md. Mizan[4]

Sanju Ghosh[5] Soumyajit Banerjee[6]

[1 2 3 4] Asst. Prof.,*Information Technology, Guru Nanak Institute of Technology*

[5 6]Student, Information Technology, *Guru Nanak Institute of Technology*

Abstract— In this work a Time Petri Net based approach has been proposed to build the automatic signaling system in Railway Network. Petri Net is a powerful tool that provides a formal mathematical modeling approach to demonstrate any Information System. In this work a variation of traditional place-transition net has been used to model the automatic signal system management in railway track and which also encompasses the safety measure in crossing region also. A state-oriented modelling approach has been adopted to demonstrate the controlling of railway track.Proposed system also notifies the Railway stations and Train engine about the situation of rail way tracks, so that trains can switch to another railroad accordingly.Finally, the proposed model has been verified using the reachability analysis of time petri net to ensure the safe and deadlock freeness of the proposed system.

Keywords—Petri Net, Time Petri Net, Information System, Automated Controller, Reachability Analysis.

Introduction

Railways play an important part in our life by connecting us throughout the country. It is a fast mode of transport and is comfortable in different ways. Railways also help in transporting goods and materials to different corners of the country. The railway network consists of various component such as train tracks, station, crossing regions, level crossing, controller switches.To ensure safe and quick transportation from one point (e.g., A) to another point (e.g., B) in a railway traffic system is a significant matter of concern.

There are many attempts to develop the safe and reliable softwareapplications have been formalized and verified based on some rigorousmathematical technique before the actual implementationstarts [1][2]. The measure needs to take for modelling safety issues [3] in crossing region unless which may cause disaster.

Even there are many other issues such as waiting in the traffic due to line or railway track maintenance and signals. Many research work attempt to build automatic railway traffic, signals can be found. In [4] a monitoring approach based ongenetic programming (GP) for synthesizing of a monitor alarmsystem for the railway control traffic unit proposed. In [5] the formal method of demonstrating various railway operation such as stations layout and timetables operation, level crossing management,trains dispatching and regularity (punctuality) monitoring using Petri Nets. In[6] also provides safety measure in railway network.

In this work a time petri net-based approach has been proposed to monitor the railway track activity and management. This work will also verify the safety and deadlock freeness of the proposed network.

This paper is organized as follows. In section 2, the basic terminology is explained, and the description of petri net model has been discussed. In section 3, proposed work for designing automatic control structure for signaling based on time Petri Nets is proposed. In section 4, Reachability tree based analysis of the proposed model is described. The Reachabilty tree and the changes of marking are described in a tabular format. In section 5, the applicability and the effect of the proposed method are demonstrated. Finally, section 6 contains concluding remarks.

I. BASIC TERMINOLOGY

A. Petri Net

A Petri net, [7,8] is a mathematical modelling languages used for the description of distributed systems. It is a directed bipartite graph, in which the nodes represent transitions and places (i.e. conditions, represented by circles). The arcs represent which places are pre- and/or postconditions for which transitions (signified by arrows). The Place- Transition Net can be define [9] as 5-tuple:

PN= (P,T,I,O, M_0) ,where
P = is the set of places {p1, p2, p3, …, pn},
T = is the set of transition { t1, t2, t3, …, tn}
Input I : T → Pr (r = number of places)
OutputO : T → Pq (q = number of places)

marking p : assignment of tokens to the places of Petri netp = p1, p2, p3, … pn, where $M_0$is the initial marking.

Reachability:

A marking M_n is said to be reachable from a marking M_0if there is a sequence of firing denoted by $=$ $0\ 1\ 1\ 2\ 2\ 3$ … … . . [17].

Boundedness:

A petri net is said to be bounded or k-bounded if the number of tokens in each place does not exceed k[17]. If k=1 , then the Petri net is marked as safe.

There are wide variety of Petri nets models can be found [10-15] which can be used to model for the study and analysis of simultaneous systems and discrete event system.

B. Time Petri Net Defination

A Time PN (TPN) is a marked PN in which a set of specifications are provided and a set of rules are defined such that to each legal execution sequence E a time execution sequence TE can be univocally associated. A time execution sequence TE of a marked PN with initial marking M(1), is an execution sequence E augmented by a non-decreasing sequence of real values representing the epochs of firing of each transition, such that consecutive transitions (t(j) ; t(j+1)) in E correspond to ordered epochs $\tau_j \leq \tau_{j+1}$ in TE. [8,16]. We are assigning the use of time petri net for a system management project which could be useful in the future. Based on time driven petri net we can control the railway traffic signal which will guide us to a safer world in transportation.

A Time Petri net (TPN) is a 6-tuple Z=(P,T,F,V,m0,I) such that
1. The 5-tuple S(Z) = =(P,T,F,V,m0) is a Petrinet
2. $I:T \longrightarrow Q0$ *(Q0 U {∞} and for each t $\in$ T, withI(t) = (I1(t),I2(t)) it holds that I1(t)<I2(t).

II. PROPOSED WORK

A. SYSTEM DESCRIPTION

Now a days railway network becoming more and more complex. Generally, in every railway network there are many stations are there in between two different cities. In our proposed framework it has been assumed that there are five stationsA, B, C, D, E are existing in our railway system. In this scenario A and E are the initial and the destination station respectively, whereas B,C and D are the substations in between A and E. It has been also assumed that A and E are the junction station from where the train can depart andcan arrive after completion of the journey. During this transition the train can change thetrack .When the train starts its journey it will choose track 1 or track 2 to reach Station E. And similarly when its starts the journey from E it will choose between track 3 or track 4.

B. PETRINET MODEL REPRESENTATION

In the figure 1 the time Petri net-based model has been proposed to demonstrate the transition from one station to another. If the train is departing from station A and is going towards station E then we are using the platforms p1,p2,p5,p6,p9 and p10 . If train is departing from station E and is going towards station A then we are using the platforms p11,p12,p7,p8,p3 and p4 . Here we are just considering about few station and make a useful model.

When a train start the journey from station A it will choose the track 1 and 3 and when a train start the journey from station D it will choose track 2 and 4 (by the controller) . There are multiple crossing in between the stations . TableI and TableII demonstrate the significance of Place and Transition.

When a train start the journey from station A, then it will wait for T=50 seconds. If it does not get any command from

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

the controller then it will choose track 1 and reach platform P1 of station B and if it has got any command in between 50 seconds then it will choose track 2 and reach platform P2 of station B and continue its journey and reach platform p6 of station C. There are multiple crossing in between the stations .From platform p1 of station B the train will wait for T=30 seconds if it has receive any command from the controller then train to go to platform p6 of station C (track 2) only if platform p5 of station C is not available for some reason (due to other train available in that track) otherwise the it will continue onwards with track 1 and advance to platform p5 of station C.

After reach P9 platform of station D it will wait for T=50 seconds and if there is no train available in station E then it will reach its destination station E or it may wait until any command from received from the controller. From platform p6 of station C the train will wait for T=30 seconds if it has not receive any command from the controller then train to go to platform p10 of station D otherwise train to go to platform p9 of station D (track 1) if platform p10 of station D is occupied. After reach p10 platform of station D it will wait for T=50 seconds and if there is no train available in station E then it will reach its destination station E or it may wait until any command from received from the controller.

Similarly if a train start its journey from station E, then it will wait for T=50 seconds. If it does not get any command from the controller then it will choose track 3 and reach platform P11 of station D and if it has got any command in between 50 seconds then it will choose track 4 and reach platform P12 of station D and continue its journey and reach platform p8 of station C. There are multiple crossing in between the stations .From platform p11 of station D the train will wait for T=30 seconds if it has receive any command from the controller then train to go to platform p8 of station C (track 4) only if platform p7 of station C is notavailable for some reason (due to other train available in that track) otherwise the it will continue onwards with track 3 and advance to platform p7 of station C.

After reach P3 platform of station B it will wait for T=50 seconds and if there is no train available in station A then it will reach its destination station A or it may wait until any command from received from the controller. From platform p8 of station C the train will wait for T=30 seconds if it has not receive any command from the controller then train to go to platform p4 of station B otherwise train to go to platform p3 of station B (track 3) if platform p4 of station B is occupied.

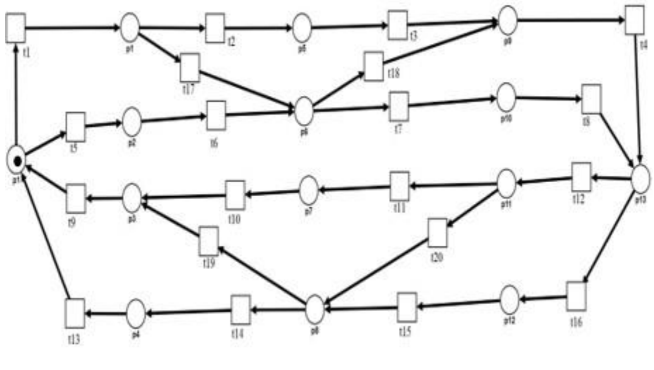

Figure1: Proposed model

After reaching p4 platform of station B it will wait for T=50 seconds and if there is no train available in station A then it will reach its destination station A or it may wait until any command from received from the controller.

In figure 2 the petrinet model has been represented in a modified format where all the transition occurring in a station is showing separately by highlighting using dotted lines.

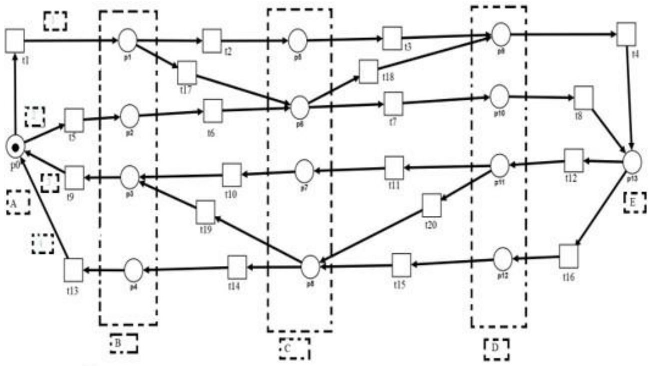

Figure2. Proposed model (showing each station activity)

Table-I

PLACES	
p0	Initial platform (station A)
p1	Platform of station B
p2	Platform of station B
p3	Platform of station B
p4	Platform of station B
p5	Platform of station C
p6	Platform of station C
p7	Platform of station C
p8	Platform of station C
p9	Platform of station D
p10	Platform of station D
p11	Platform of station D
p12	Platform of station D
p13	Destination platform(station E)

TABLE II

TRANSITIONS	
t1	Way from p0 to p1
t2	Way from p1 to p5
t3	Way from p5 to p9
t4	Way from p9 to p13
t5	Way from p0 to p2
t6	Way from p2 to p6
t7	Way from p6 to p10
t8	Way from p10 to p13
t9	Way from p3 to p0
t10	Way from p7 to p3
t11	Way from p11 to p7
t12	Way from p13 to p11
t13	Way from p4 to p0
t14	Way from p8 to p4
t15	Way from p12 to p8
t16	Way from p13 to p12
t17	Way from p1 to p6
t18	Way from p6 to p9
t19	Way from p8 to p3
t20	Way from p11 to p8

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 06 | June - 2022 Impact Factor: 7.185 ISSN: 2582-3930

III. RECHABILITY TREE BASED ANALYSIS OF ALGORITHM

In table III the changes of marking has been mentioned for the proposed model, and in figure 3 the reachabilty tree has been designed using reachability analysis technique.

Table-III

	p0	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	p11	p12	p13
M0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
M1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
M2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
M3	0	0	0	1	0	0	0	0	0	0	0	0	0	0
M4	0	0	0	0	1	0	0	0	0	0	0	0	0	0
M5	0	0	0	0	0	1	0	0	0	0	0	0	0	0
M6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
M7	0	0	0	0	0	0	0	1	0	0	0	0	0	0
M8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
M9	0	0	0	0	0	0	0	0	0	1	0	0	0	0
M10	0	0	0	0	0	0	0	0	0	0	1	0	0	0
M11	0	0	0	0	0	0	0	0	0	0	0	1	0	0
M12	0	0	0	0	0	0	0	0	0	0	0	0	1	0
M13	0	0	0	0	0	0	0	0	0	0	0	0	0	1

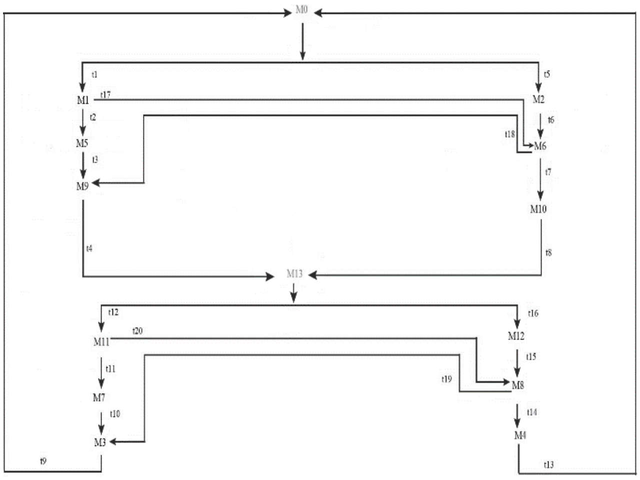

Figure3: Reachability Tree

IV. RESULTS

By analyzing the proposed Petri net model it is found that –

- The net is safe as in every place there is only one token is available and after firing a sequence of transition also it does not exceed the quantity one.
- In the system all the places can be reached by firing of transition from anywhere in the complete network hence the designed system is reachable .
- As the system is reachable hence the deadlock freeness can be ensured.

V. CONCLUSION

In this work a time petri net-based model has been proposed to build the automatic signaling system in Railway Network. and analyzed to ensure the deadlock freeness. Fordesigning the automatic signal system timePetri net model which is a subclass of petri net model has been used. In this work thestructural reachability of the model has been analyzed. As we know that the structural reachability is concerned withconnectivity hence it is ensured that the connection between source and destination node has been maintained properly in wholediagram.

REFERENCES

[1] Heitmeyer, C. (2006). Developing safety-critical systems: the roleof formal methods and tools. In Proceedings of the 10th Australianworkshop on Safety critical systems and software-Vol. 55, pp. 95-99.

[2] Strunk, E. A., Yin, X., & Knight, J. C. (2005). Echo: a practicalapproach to formal verification. In Proceedings of the ACM 10thinternational workshop on Formal methods for industrial criticalsystems (pp. 44-53).

[3] Smith, J., Russell, S., &Looi, M. (2003). Security as a safety issue in rail communications. In Proceedings of the 8th Australian workshop on Safety critical systems and software-Vol. 33 pp. 79-88.

[4] G.I.Daian, M.M.Santa, T.S.Letia; Evolutionary Method for Railway MonitoringSystems; Proceedings of the 18th International Conference on System Theory,Control and Computing, Sinaia, Romania, October 17-19, 2014

[5] Stefano R; The use of Petri Nets models in railway traffic applications;2nd IFAC Workshop on Dependable Control of Discrete Systems DCDS'09; Bari, Italy, June 10-12, 2009.

[6] Carlson, A., Frincke, D., & Laude, M. (2003). Railway security issues: A survey of developing railway technology. In Proceedings of the International Conference on Computer, communications and Control Technologies Vol. 1, pp. 1-6.

[7] J. M. Couvreur , E. Encrenaz , E. Paviot-Adet , D. Poitrenaud , and P. A. Wacrenier, "Data decision diagrams for Petri net analysis", Application and Theory of Petri Nets, pp. 101-120, Springer Berlin Heidelberg, 2002.

[8] B. Berard , F.Cassez , S. Haddad , D. Lime , and O. H. Roux, "The expressive power of time Petri nets," Theor. Comput.Sci., vol. 474, pp. 1–20, February 2013.

[9] Farooq Ahmad, Ayesha Sadiq, Martinez-Enriquez A.M. Muhammad Aslam, Waqas Anwar, Usama Ijaz Bajwa,Mudasser Naseer7, Sher Afzal Khan; Component based Architecture for the Control of Crossing Regions in Railway Networks; 2017 16th IEEE International Conference on Machine Learning and Applications, pp: 540-545.

[10] My El Hassan Charaf; Salma Azzouzi "A colored Petri-net model for control execution of distributed systems"2017 4th International Conference on Control, Decision and Information Technologies (CoDIT) Year: 2017Pages: 0277 – 0282

[11] C. Sibertin-Blanc , "High level Petri nets with data structure", 6thEuropean workshop on Application and Theory of Petri Nets, pp. 141-el141-elsinki, Finland, 1985.

[12] R. Davidrajuh , "Activity-Oriented Petri Net for Scheduling of Resources", 2012 IEEE International Conference on Systems, Man,

and Cybernetics (IEEE SMC 2012), Seoul, Korea, October 14-17,2012.

[13] Elhillali K, Allaoua C, Ouassila L, et al. A UML and Colored Petri Nets Integrated Modeling and Analysis Approach using Graph Transformation [J]. Journal of Object Technology. 2010.9(4):25-43

[14] M. A. Holliday, M. K. Vernon, "A Generalized Timed Petri Net Model for Performance Analysis", Software Engineering, IEEE Transactions on, 12: 1297 – 1310, December 1987.

[15] Fabio Lima; Matheus F. R. Cortez; Patricia P. Schmidt; Ana Karoline Silvério; João Chang "Petri net application in simulation of ambulatory processes" IECON 2015 - 41st Annual Conference of the IEEE Industrial Electronics Society ,Pages: 004696 – 004701

[16] Chapman, Nick(1997) – Surprise97 journal on Petri Nets Models.

[17] Tadao Murata — Petri Nets: Properties, Analysis and Application‖, Proceedings of the IEEE, Vol.77, No.4, April 1989.