Reduction of Delay Rate in Open Queueing Network

K.Banu Priya, P.Rajendran

Abstract: A new method namely, Reducing Delay Method (RDM) is proposed for the open queueing network (OQN) and deterministic timed petri nets (DTPN). The main aim of the RDM is to find a minimum reduced delay rate which occurs in the airports. Airspace transportation plays an important role in passenger's travels and passengers face more delay issues in airport queues. The flight delay by because report collected through the Operations Network (OPSNET). OPSNET is used to analyze the performance of the Federal Aviation Administration (FAA). By using the RDM, it is found that the delay rate is very much reduced and is shown with the help of a numerical example.

Index Terms: Airport, Delay rate, Deterministic timed petri nets, Open queueing network, Operations network, Petri nets, waiting time

1 INTRODUCTION

In open queueing network, we have two types: they are feed forward and feed backward open queueing network. This system gets passengers or their arrivals from outsources.
Jackson queueing Network is an example for open queueing network. Now-a-days, we find that the delay of the flight from one airport to another is caused due to weather, equipment, volume, runway etc. Many researchers used queueing network model to analyze the total network delay rates. Baspinar et. al [6] created a model called airport based queueing network for analyzing a total network delay ,and observed that critical values of airport and the airport which comes under this critical value will be of significant value of a total delay and RoshliAniyeri et. al [13] analysed passenger queue in international airports, using multi-server queueing model. Andrea Bobbio [1] explained PN in graphical form. Balbo.G et al. [3] combined the QN and GSPN to obtain the solution of complex models of system behavior. Bauseet. al [4] analyzed combination of queueing and petri nets. Bauseet. al [5] combined petri nets and queueing network models to explain scheduling strategies. Angela Di Febbraroet. al [2] combined deterministic and stochastic petri nets to control congestion in urban areas. JiacunWang [9] found that the Dynamic event-driven system (DEDS) is used to model systems like computer network, communication systems, manufacturing plants, command and control systems, real time systems and logistic networks proved the efficient models and tools for urban traffic systems. KokMun Ng et. al [10] outlined the related works conducted, using the PN's and discussed its variability.Jianli et. al [8] made a study on the models of flight delays chain reaction based on time petri nets. Xiaoyanet. al [14] preferred time petri nets model to reduce the complexity of the flight delay level in downstream airports and Hui Fu et. al[7] preferred colored petri nets to reduce traffic between two sub-regions. Monish Tandaleet. al [11],chosen open Jackson queueing network to capture intra-center flow with an analyzed performance of national airspace system and it is used to analyze uncertainties on traffic flow. MozafarRoshaniet.al[12], chose queueing petri nets model to analyse the performance of internet protocol.

2 PRELIMINARIES

2.1 Petri Net

Petri nets is a five-tuple, N={P,T,I,O, M_0 }.

i. P-Place = $\{p_1, p_2 \dots p_m\}$ is a finite set, called place.
ii. T-Transitions = $\{t_1, t_2 \dots t_n\}$ is a finite set, called transitions.
iii. I-P×T→N is an input function.
iv. O-T×P→N is an output function.
v. M_0 – Initial marking.

The following figure (Fig.1) is an example for petri nets.

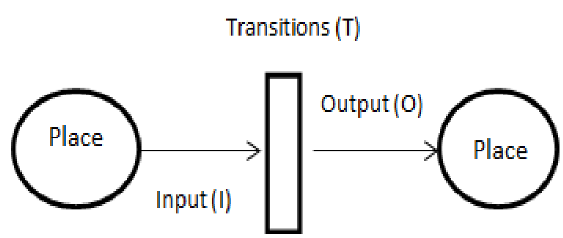

Fig. 1 *Petri Nets*

2.2 Deterministic Timed Petri Nets (DTPN's)

A Deterministic timed petri nets (DTPN's) is a six tuple given by (P,T,I,O, M_0, τ), where (P,T,I,O) is a petri net and τ:T→ R^+ is the mean firing time for deterministic time delay. A DTPN's transition t_i can fire τ if and only if

(i) In transition any input place p may have tokens, those numbers of tokens should be equal to the weighted of the directed arc, which connects p to t_i with the time interval $(\tau - \tau_i, \tau)$, τ is the firing time of transition t_i .

(ii) After completing transition fire, output place of transition p will get number of tokens equal to weight of the directed arc which connects t_i to p at time τ .

2.3 Application of DTPN's

Application of DTPN's is to calculate the net time of a simple petri nets model. The petri nets place should have one input arc and one output arc. From the network protocol, we consider a minimum network (Maximum performance) X_n as defined by

$$X = \max\left\{\frac{T_n}{N_n} : n = 1, 2, \ldots, q\right\}$$

Where,

$T_n = \sum_{t_i \in L_k} \tau_i$ = sum of the execution times of the transitions in net n;

$N_n = \sum_{p_i \in L_k} M(p_i)$ = total number of tokens in the places in net n;

q = number of nets in the network.

2.4 Queueing Network

The Network that consists of several queues is called queuing network.

3 JACKSON OPEN QUEUING NETWORK FOR PERFORMANCE MEASURE

The Jackson open queueing network for performance measure is given in the following Fig-2.

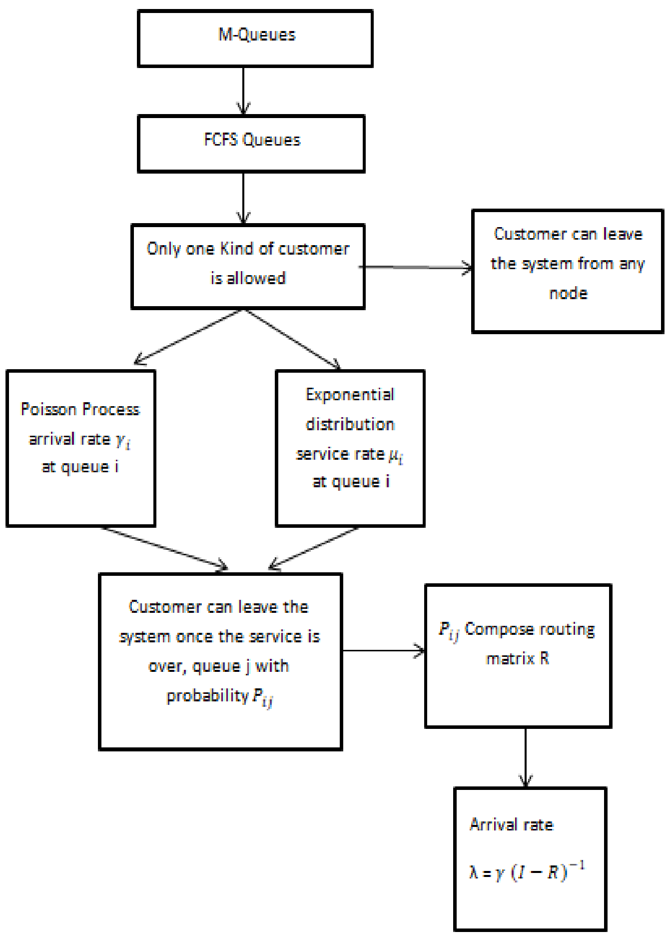

Fig. 2 *Jackson Open Queueing Network For Performance Measure.*

I represent identity matrix and R represent routing matrix. Each node of the network is taken as independent M/M/1 queue rate of arrival is (λ_i) and rate of service is (μ_i).

Since each queue is unique M/M/1 with ρ_i .

Traffic intensity, $\rho_i = \frac{\lambda_i}{\mu_i}$.

Length of the network, $L_i = \frac{\rho_i}{1-\rho_i}$.

Waiting time of passengers in the network,

$$W_i = \frac{1}{\mu_i - \lambda_i}$$

Average number of passengers in network,

$$LN = \sum_{i=1}^{m} L_i = \sum_{i=1}^{m} \frac{\rho_i}{1-\rho_i}$$

Total average load on network,

$$\gamma N = \sum_{i=1}^{m} \gamma_i$$

Average delay through network,

$$WN = \frac{LN}{\gamma N} = \frac{1}{\gamma N}\sum_{i=1}^{m}\frac{\rho_i}{1-\rho_i} = \sum_{i=1}^{m}\frac{\lambda_i}{\gamma N} W_i$$

4 RDM AND IMPLEMENTATION OF OPERATIONS NETWORK (OPSNET) DELAY DATA

4.1 OPSNET Delay Data

Operations network (OPSNET) collects delay data's every day from federal aviation administration air traffic. We consider the data obtained from delay data's of Airport from (OPSNET).
We consider the reportable delays only. Weather, Volume, Runway, Equipment and others are the reportable delays by the causes.

4.2 Reducing Delay Method

The following steps are given by the RDM.
STEP 1: Construct a simple network protocol, using the data available/obtained.

STEP 2: Find the minimum net time from the network protocol as per the (DTPN's) minimum net (that is at the maximum performance level).

STEP 3: Construct open queueing network model of a minimum net time for the above network protocol.

STEP 4: Now, use the Jackson open queueing network for performance measure and find the routing matrix. With this routing matrix, calculate the total traffic flow and the average minimum delay.

STEP 5: Now, compare the DTPN's minimum time and Jackson open queuing network for performance measures average minimum delay and finalizes the minimum delay of the RDM.

5 NUMERICAL EXAMPLE

Now, we consider the data obtained from delay data of Airport from (OPSNET) which is given in Table-1.

Table 1: *OPSNET-Delay by cause report (Atlanta).*

Delay by Causes	Delays
Weather	**3**
Volume	**9**
Equipment	**0**
Runway	**0**
Other	**0**
TOTAL	**12**

Construct the simple network protocol between arrival and departure as given in Fig.3.

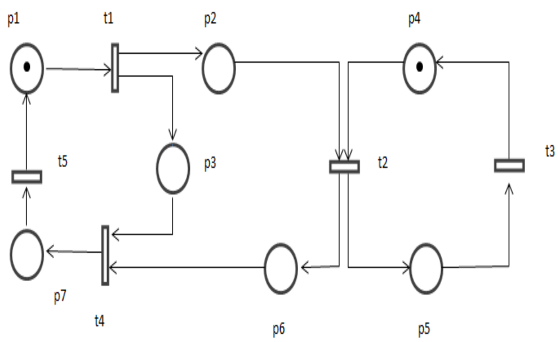

Fig. 3 *Simple network protocol*

Now, we find the minimum net time from the network protocol as per the (DTPN's) minimum net (that is at the maximum performance level).

$$p_1 t_1 p_3 t_4 p_7 t_5 p_1 : X_1 = \frac{T_1}{N_1} = 0$$

$$p_1 t_1 p_2 t_2 p_6 t_4 p_7 t_5 p_1 : X_2 = \frac{T_2}{N_2} = 12$$

$$p_4 t_2 p_5 t_3 p_4 : X_3 = \frac{T_2}{N_2} = 9$$

Now, we construct the open queueing network model of the minimum net time for the above network protocol which is given in Fig.4.

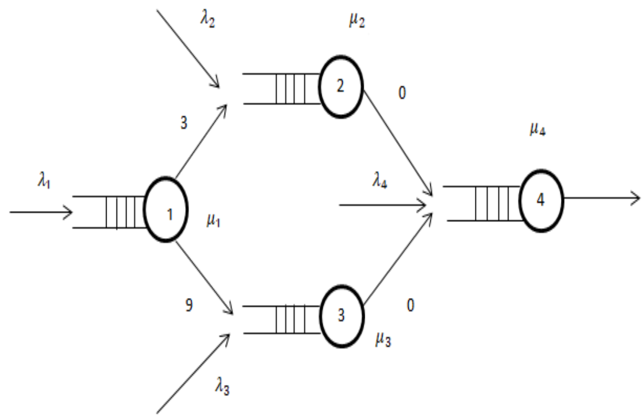

Fig. 4 *Open Queueing Network Model*

Now, we use the Jackson open queueing network for performance measure (Fig 2.) and obtain the routing matrix R which is given below:

$$R = \begin{bmatrix} 0 & 3 & 9 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

With this routing matrix, we calculate the total traffic flow and the average minimum delay as given below:

Now, we obtain the traffic equation given by $\lambda = \gamma(I - R)^{-1}$, where γ is the Poisson external arrival and is considered as

γ = (0.5,0.25,0.75,0.5)

And is found to be

$\lambda = [0.5, 1.75, 5.25, 0.5]$.

Now, we use Exponential service rate μ = (3,9,0,0).

We obtain the traffic intensity,

$\rho = \lambda / \mu = [0.167, 0.195, 0, 0]$.

Now, we find the Average number of passengers LN, in open queueing network and is given by

$$LN = \sum_{i=1}^{m} \frac{\rho_i}{1 - \rho_i} = 0.4422$$

Now, we determine the total average load on open queueing network, denoted by γN and is found to be

$$\gamma N = \sum_{i=1}^{m} \gamma_i = 2$$

Now, using the total average load on open queueing network, we obtain the average delay, denoted by WN and is found to be,

$$WN = \frac{1}{\gamma N} \sum_{i=1}^{m} \frac{\rho_i}{1-\rho_i} = 0.2211$$

Now, we compare the results obtained for the delay rate of OPSNET, DTPN's and OQN and is given table-2

TABLE 2: *COMPARISONS OF DELAY RATES*

CAUSES	TOTAL DELAY
OPSNET	12
DTPN'S	12
OQN	0.2211

From table-2, we find that, the delay rate of OPSNET has been reduced from 12 to 0.2211 by using the introduced RDM.

6 CONCLUSION

This paper has presented a new method namely, RDM to reduce the flight delay rates in airports together with the deterministic timed petri nets (DTPN) and open queueing network (OQN). The flight delay data collected through the Operations Network (OPSNET) is used to analyze the performance of the Federal Aviation Administration (FAA). It is found that the delay rate is very much reduced, and is shown with the help of a numerical example.

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