Indian Institute of Technology Guwahati
Department of Mathematics
MA402
Queuing Models using performance Analysis

Summary Report

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Topic: Elevator Configuration Based on the Markov Network Queuing Model

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Summary

We can see the ubiquitous presence of Elevators as a mode of transport in almost all the skyscrapers and buildings, where the elevator traffic generally remains high. So it is necessary to model these elevators properly according to traffic variations of a particular building. This requires we analyze the elevator traffic reasonably. The traditional approach used for this supposes the car number and the carrying capacity of car firstly, then analyze the elevator system's performance on the basis of this supposition. If the performance is dissatisfactory, supposition is modified and calculations are again done till they reach the satisfactory performance. The traditional way not only needs much time but it is also not very reasonable because it does not take into account the influence of many factors in configuration such as the randomness of passenger's arrival, the asymmetry of passenger's number on each floor, the height difference of each floor and so on. Keeping these things in mind, Markov Network theory has been applied to model the elevator traffic in this paper.

The model discussed in this paper considers a 100 store building with two sky lobbies employed at 30th and 60th floors, to reduce waiting time. This divides the building into 3 halves, lower floor section, middle section and high section. This paper primarily deals with 'Uppeak' traffic only which is traffic modeling when the users are traveling from bottom to some higher floor. It is assumed that once we model it successfully for Uppeak traffic, it works fine for 'Downpeak' traffic also [1]. In this condition, we apply Jackson open network to build the elevator serving system model (see in Fig. 1). Where **'1'** represent the elevator queue system of the lobby, **'2'** represent the elevator queue system of the 30th air lobby in the building and **'3'** represent the elevator queue system of the 60th air lobby in the building. There are M (M=3) service stations in this model. Every station has its own queue. The No. 'i' station includes ***'mi'*** elevators which obey exponential distribution with the service rate of ***'pi'*** .The input of the No. 'i' station is Poisson Flow with parameter of ***'Ai'*** **,** ***i*** **= 1,2,3** . The inputs of each station are independent to each other.

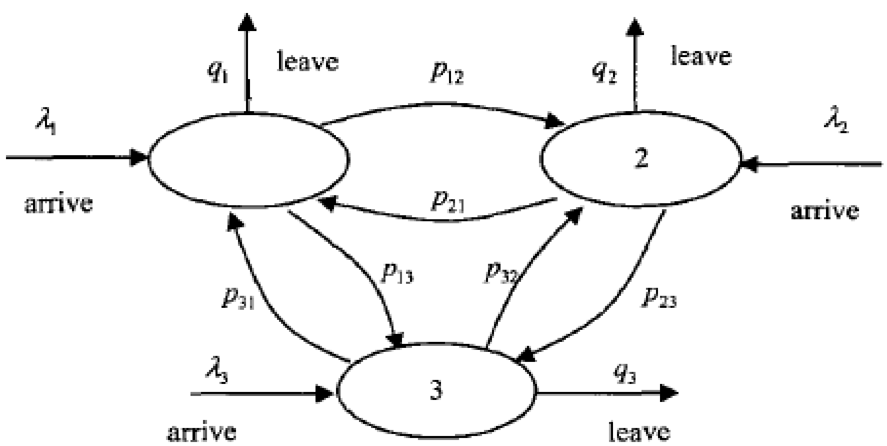

Figure 1. Model for the Elevator with 3 sky lobbies

After receiving the service of No. i station, the passengers enter the No. j station with the possibility of ***pij*** and leave the system ***M*** with the possibility of $q_i = 1 - \sum_{j=1}^{M} p_{ij}$ **.** The network queue can be expressed as a vector of M dimensions, n = (n_1, n_2, . . . , n_M) where n_i is the queue length of No. i station. In the network model, three queue systems can be reduced to the typical queue system model E_m/M/n.

Elevator Configuration of Service Station No. 1

For official building, we usually use time interval t_{in}, = 30s and intensity of elevator service p < 1 .O [2] as the target function to configure elevator. Here we calculate the various parameters required to model an elevator. We suppose the probability of passengers entering each floor is the same. The passengers total arrival rate A_i of each station can be calculated using [3]

$$\begin{bmatrix} \Lambda_1 \\ \Lambda_2 \\ \Lambda_3 \end{bmatrix}^{\mathrm{T}} = \begin{bmatrix} \lambda_1(1-q_1) \\ \lambda_2(1-q_2) \\ \lambda_3(1-q_3) \end{bmatrix}^{\mathrm{T}} \begin{bmatrix} 1 & -p_{12} & -p_{13} \\ -p_{21} & 1 & -p_{23} \\ -p_{31} & -p_{32} & 1 \end{bmatrix}^{-1}$$

For ‘Uppeak’ traffic condition, all passengers enter the system **M** from the bottom floor. So A2 = A3 = 0. Please note that A1, A2, A3 denote the lambdas in the above formula. The passengers total arrival rate A1, A2, A3 can be calculated as,

Station 1: (Lobby of the office building) A1 = λ_1.

Station 2: (Middle Lobby at 30th floor) A2 = $p_{12}\lambda_1$.

Station 3: (Upper Lobby at 60th floor) A3 = $p_{13}\lambda_1$.

Time taken to reach a particular floor can be calculated as: $t_v = \frac{d_c}{v}$.
Here d_c is the floor height and v is the speed of the cable car.
The stopping time can be calculated as $t_s = t_c + t_o + (t_1 - t_v)$, where t_c is the closing time of the door, t_o is the opening time of the door, t_1 is the time that the car passes the floor really cost. Calculating t_{int}, the estimate of car’s running interval.

$$t^{(k+1)} = t^{(k)} - \varpi_k \frac{f(t^{(k)})}{f'(t^{(k)})}$$

where ***t*** represents t_{int} , w_k is the descending gene. Choosing w_k = 0.5, we can calculate t_{int} using iterative method. Calculating the number of passengers arrived during the interval.
p = Auppeak * t_{int}

Calculating the average highest floor of car's returning,

$$H = \sum_{i=1}^{n} iP\{H = i\} = \sum_{i=1}^{n} i(e^{-\frac{P}{n}})^{n-i}(1 - e^{-\frac{P}{n}})$$

Calculating the expected value of car's stopping,

$$S = np = n(1 - e^{-\frac{P}{n}})$$

Using these basic parameters we can model the elevator system and also calculate other higher parameters, which have been already discussed in the paper.

Similarly for the other two 30th and 60th floors, we can analyze in the same manner. The only difference between them is their service parameter explained as follow. The building section served by the station No.2 is floor 30-59. In this section the passenger's total arrived rate is $A, = p_{l2*} A1$. The building section served by the station No.3 is floor 60-100. In this section the passenger's total arrived rate is $A3 = p_{13}*A2$ *(denotes lambda here)***.** In the elevator configuration of the service station No.2 and No.3, we only need to replace *A***,** in the configuration of No. 1 with *A2* and *A3*. Then just following the configuration steps in station No. 1, we will get the configuration result and the system performance for these floors also.

Conclusion

So this method presents a very novel method to model the elevator traffic and hence calculate its various parameters. It has many advantages over the traditional approach. Using this approach, we can predict the building's traffic on the basis of other similar building's factual traffic. Then we can configure the elevator for the building based on the predictive traffic condition. The results of this method have been discussed in the paper and have been proved to be more correct and reliable. Consumer also has the capability to modify the configuration based on his/her requirements.

References:

[1] Chapter 13: Elevator Traffic Handbook: Theory and Practice, By Gina Carol Barney

[2] Barney G C, Dos S M, "Elevator traffic analysis, design and control". *IEEE, Peter PeregUnus*, London, 1985.

[3] Brannon John, "Independent consultant, elevator traffic analysis and selection for smaller buildings", *Elevator World*, 1998, May: 86-87.