International Journal of Computing and Network Technology

http://dx.doi.org/10.12785/ijcnt/010206

Enactment of Stochastic Model Stream Mechanism on Multi class Queueing Network

K.Sivaselvan[1], C.Vijayalakshmi[2]

[1]*Department of Mathematics, Jeppiaar Engineering College, Chennai.*
[2]*Department of Mathematics, VIT University, Chennai.*
Email Address: sivajpr@gmail.com, vijusesha2002@yahoo.co.in

Received: 14 Jan. 2013, Revised: 17 Feb 2013; Accepted: 12 Mar. 2013
Published online: 1 May 2013

Abstract: Over the last few decades stream control mechanism has more attention in the early stages of research in communication network. The motivation of this work is deep understanding on the stream control mechanism problem in multi-class networks. In this paper, game theoretic perspectives are presented and the appropriate frame work for the study of stream control mechanism problem is analysed. Consider a min-max routing problem, where the control mechanism has to decide to which of N queues that the arriving customer should be sent. The service rate in each queue is dependent on the state of the system, may change in time and is unknown to the control mechanism. The goal of the control mechanism is to design an efficient policy which guarantees the best performance under the worst case service conditions. ie., Arriving customers are routed by a control mechanism, with the purpose of minimizing the total discounted holding cost under worst-case service conditions. Then the problem is viewed as a zero-sum (Stochastic)Markov game between the routing control mechanism and a service control mechanism. In zero-sum (Stochastic)Markov game, where the server acts as player 1 and the stream control mechanism acts as a player 2. Each player is assumed to have the information of all the previous actions of both players as well as the current and the past states of the system. The main results obtained are to identify the optimal strategy for both players. A value iteration technique is used to establish properties of the value of the game, which are related to super modularity and convexity.

Keywords: Zero-sum (Stochastic)Markov games, control mechanism of queuing networks, Multi class networks, supermodularity and convexity, value iteration.

I. Introduction

Optimal resource allocation is one of the most important tasks to be resolved in computer network. Resource allocation can be divided into three parts stream control mechanism, routing and buffer management. These management tasks will affect the performance of computer network. If the stream control mechanism is prepared aptly, then the probability for nodal blocking and deadlock is reduced very much. The stream control mechanism principle is shift to congestion control mechanism form the interior of the network to the points of traffic admittance. Consider a problem of dynamic stream control mechanism of arriving customer into a finite buffer in which at most one customer can join the system with respect to time slot. In this system, consider one user control mechanism the dynamic stream of arriving customer into a buffer and the congestion phenomena is modeled by the other users. The service rate in each queue is dependent on the state of the system, may change in time and is unknown to the control mechanism. The main aim of the control mechanism is to design a control mechanism strategy that guarantees the best performance under the worst-case service conditions. Formulate this problem as a zero-sum (Stochastic)Markov game between the routing control mechanism and a service control mechanism. In zerosum (Stochastic)Markov game, where the server acts as player 1 and the stream control mechanism acts as a player 2. A value iteration technique is used to solve this problem, which shows an optimal policy for the stream control mechanism. ie., The stream control mechanism decreases the input stream as the number of customer increases and the Quality Of Service (QoS) decreases with the number of customers in the queue , under the worst-case service conditions. The property of the value function shows the optimal strategy which are related to super modularity and convexity.

II. LITERATURE SURVEY

The Stream control mechanism using theory of zero-sum Markov games had been developed by E.Altman(1994). A.D. Bovopoulos. (1989) had elaborated the concept of Resource allocation algorithms for packet switched networks. S. Andradotir. et.al.,(2001) has clearly envisaged the server assignment policies for maximizing the steady state throughput of finite queueing systems. W.Ching.et.al.,(2009) has analyzed the optimal service capacities in a competitive multiple-server queueing environment . C. Douligeries et.al.,(1988) had clearly explained a game theoretic approach to stream control mechanism in an integrated environment with two classes of users. A.A. Economicdes.et.al.,(1990) the routing and congestion control mechanism in distributed computed systems as a nash game. M.El-Taha.et.al.,(2006) had approached the allocation of service time in a multi server system. M.T.T. Hsiao.et.al.,(1987)had given a detailed explanation optimal stream control mechanism of multi-class queueing networks with decentralized information. The congestion control mechanism in computer networks had clearly explained by R. Jain (1990).

III. STOCHASTIC SPECULATIVE MATHEMATICAL MODEL OF A SYSTEM

Consider a system of single server queue with finite buffer of size K and assume that a customer may join the system in a time slot. Let X_t denotes the number of customers in the system at time t, t = 0,1,… and the state space is denoted by $X = \{0,1,...,K\}$. Let $g_{\max}$ be a real number satisfying , $0 < g_{\max} < 1$. If the stream control mechanism chooses a player 2 in a finite set F_x , at the beginning of the each time slot. If the router chose an action i at time t , that has the interpretation that the customer has routed to queue i with the probability of an arrival with respect to time slot. This interpretation is adequate to consider the length of the queues as the state of the system. If action a_i is chosen at time t then a customer can enter the system in [t, t+1) with probability a_i

Let $p_{\min}$ and $p_{\max}$ If the queue is empty at the end of time slot which means that a customer has receive a successful service with probability $p \in \Omega$, where $\Omega \in \lfloor p_{\min}, p_{\max} \rfloor$. If the service fails the customer remains in the queue and if it succeeds the customer leaves the system and the value p represents the quality of service. The main objective of the stream control mechanism is to find the best strategy under the worst case service conditions. At the end of the time slot a customer may leave the system with probability p . The state X_t denotes the number of customers in the system at time t , $t \in IN$, and A_{1_t} and A_{2_t} denotes the events of the server and the stream control mechanism.

For any number $\xi \in [0,1]$, the transition law l is :

$$l(u/v;p;s) := \begin{cases} \bar{p}s, & \text{if } K \geq v \geq 1, u = v-1 \\ ps + \bar{p}\,\bar{s}, & \text{if } K \geq v \geq 1. u = v \\ p\bar{s}, & \text{if } K > v \geq 0, u = v+1 \\ 1 - p\bar{s}, & \text{if } u = v = 0 \end{cases}$$

Assume the pay off $C(v,p,s)$, which the router has to pay at each step if the state is v and the events p , s is separable and has the form

$$C(v,p,s) := c(v) + \omega p + \varphi u \text{ , for all } v \in X_t,\ p \in \Omega,$$

where c(v) is a real-valued non decreasing convex function on IN and ω and φ are constants , c (0) ≥ 0

Let γ be a fixed number in [0,1) and the discounted cost is :

$$V_\gamma(v,m,n) := E^{m,n}\left[\sum_{t=0}^{\infty} \gamma^t C(X_t, A_{2_t}, A_{1_t}) \mid X_0 = v\right],$$

where m and n are the policy of player 1 and player 2.

The γ - discounted value of the game is

$$V_\gamma(v) := \sup_{m \in M} \inf_{n \in N} V_\gamma(v,m,n), \text{ for all } v \in X_t$$

Then there exists a pair of stationary policies (m* , n*) that achieves

$$\sup_{m \in M} \inf_{n \in N} V_\gamma(v,m,n) = \inf_{n \in N} \sup_{m \in M} V_\gamma(v,m,n) = V_\gamma(v,m^*,n^*)$$

where (m*,n*) are called optimal policies.

A. OPTIMAL STRATEGIES

The sufficient conditions for the structure of an optimal stationary policy of player 1 and player 2 that achieves the supremum and infimum in the matrix game $V_\gamma(v) = T_\gamma V_\gamma(v)$. A value iteration technique is used to establish properties of the value of the game that are related to super modularity and convexity. This is iterative technique, for every function $f \in \kappa$ such that

$\lim_{n \to \infty} T_\gamma{}^n f = V_\gamma$ which posses the properties is also. The function

$$f : X \text{ x } \{1,2\} \text{ x } \{1,2\} \to \Re$$

satisfies the following Monotone and Integer-Convex properties.

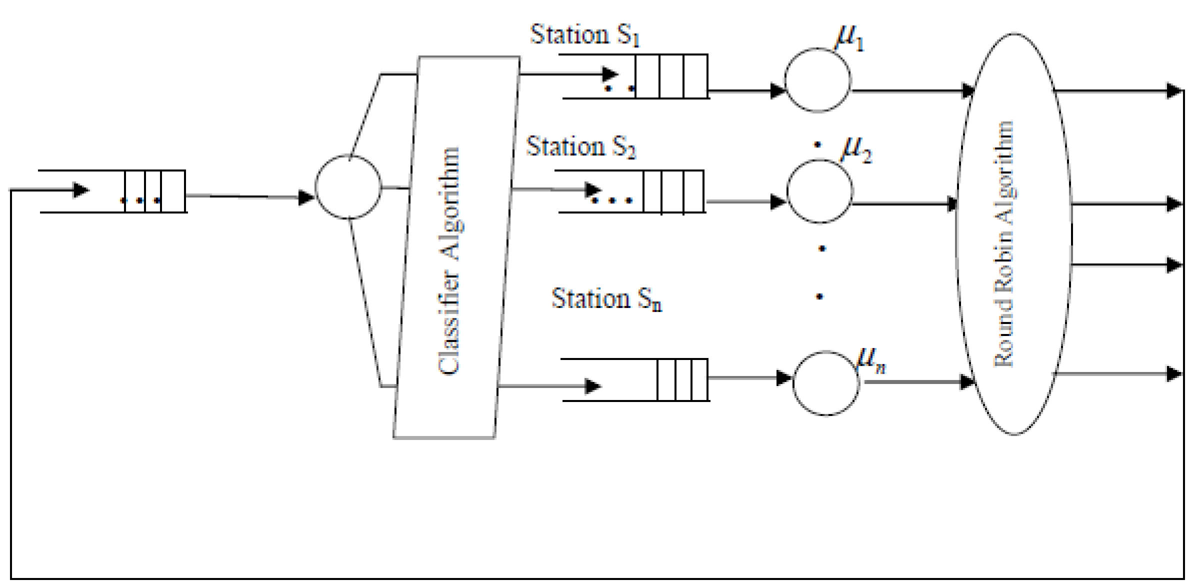
P1: If $f(x, i, 2) - f(x, i, 1)$ is monotone decreasing in x for i = 1, 2.
P2: If $f(x, 2, j) - f(x, 1, j)$ is monotone increasing in x for i = 1, 2.
P3 : If $f(x, 1, 1) - f(x, 2, 1) \le f(x, 1, 2) - f(x, 2, 2)$ for $x \in X$.
P4 : If $f(x+1, 2, 1) - f(x+1, 2, 2) \le f(x, 1, 1) - f(x, 1, 2)$ for $x \in X$.
P5 : If $f(x+1, 1, 2) - f(x+1, 2, 2) \le f(x, 1, 1) - f(x, 2, 1)$ for $x \in X$.
P6 : If $f(x+2, i, 2) - f(x+1, i, 1) \ge f(x+1, i, 2) - f(x, i, 1)$ for $x \in X$, i = 1, 2
P7 : If $f(x)$ is integer convex in x then for any
$x \in X$, $f(x+2) - f(x+1) \ge f(x+1) - f(x)$.
P8 : If $f(x)$ monotone increasing in x then for any $x \in X$, $f(x+1) \ge f(x)$.

B. QUEUES WITH HINDERING

In this section , multiple class routing problem is discuss based on the application of game theory. Consider a queuing system of “n” servers which are shared by the routing problem of two class of packets α and β, where one class of packets may be queued at the buffer and the other are blocked when it exceeds the space. The class α packets can be queued, while the class β packets are blocked. Consider the two cases for the above queueing systems;

(i) the blocking threshold for class β packets is greater than or equal to the number of servers, ie., $N \ge m$

(ii) the blocking threshold for class β packets is less than or equal to the number of servers, ie., $N \le m$.



Case (i) : $N \geq s$

Consider the case where the blocking threshold N for class β packets is greater than or equal to the number of servers s . The steady state probability of 'n' packets in the system

$$\pi_n \text{ is } \left(\frac{\lambda^\alpha + \lambda^\beta}{\mu}\right)^n \frac{\pi_0}{n!} \text{ for } n \leq s$$

The probability that a class β packets is lost then

$$P[n \geq M] = \left(\frac{\lambda^\alpha + \lambda^\beta}{s\mu}\right)^{M-s} \left(\frac{\lambda^\alpha + \lambda^\beta}{\mu}\right)^s \frac{\pi_0}{s!\left(1 - \frac{\lambda^\alpha}{s\mu}\right)} \quad ,$$

$$\text{where} \quad \pi_0 = \left[\sum_{n=0}^{s-1}\left(\frac{\lambda^\alpha + \lambda^\beta}{\mu}\right)\frac{1}{n!} + \left(\frac{\lambda^\alpha + \lambda^\beta}{\mu}\right)^s \frac{1 - \frac{\lambda^\alpha}{s\mu} - \frac{\lambda^\beta}{s\mu}\left(\frac{\lambda^\alpha + \lambda^\beta}{\mu}\right)^{M-s}}{s!\left(1 - \frac{\lambda^\alpha}{s\mu}\right)\left(1 - \frac{\lambda^\alpha + \lambda^\beta}{s\mu}\right)}\right]^{-1}$$

The overall average packet delay is:

$$\overline{A} = \frac{\overline{Q}}{\lambda^\alpha + \lambda^\beta(1 - P[n \geq M])}$$

, where $\overline{Q}$ is the average number of packets in the system.

The average packet delay for class α is:

$$\overline{A}^\alpha = \sum_{n=0}^{s-1}\frac{\pi_n}{\mu} + \sum_{n=m}^{\infty}\left(\frac{n - s + 1}{s\mu} + \frac{1}{\mu}\right)\pi_n$$

Case (ii) : $N \leq s$

Consider the case where the blocking threshold N for class β packets is less than or equal to the number of servers s . The steady state probability of 'n' packets in the system π_n is

$$\left(\frac{\lambda^\alpha + \lambda^\beta}{\mu}\right)^n \frac{\pi_0}{n!} \text{ for } n \leq N$$

The blocking probability for class β packets is

$$P[n \ge M] = \pi_0 \left[\left(\frac{\lambda^\alpha + \lambda^\beta}{\mu} \right)^N \sum_{n=0}^{s-N} \left(\frac{\lambda^\alpha}{\mu} \right)^n \frac{1}{(N+n)!} + \left(\frac{\lambda^\alpha}{\mu} \right)^{s-N} \left(\frac{\lambda^\alpha + \lambda^\beta}{\mu} \right)^N \frac{1}{s!} \frac{\left(\frac{\lambda^\alpha}{\mu s} \right)}{\left(1 - \frac{\lambda^\alpha}{\mu s} \right)} \right]$$

where

$$\pi_0 = \left[\sum_{n=0}^{N} \left(\frac{\lambda^\alpha + \lambda^\beta}{\mu} \right)^N \frac{1}{n!} + \left(\frac{\lambda^\alpha + \lambda^\beta}{\mu} \right)^N \sum_{n=0}^{s-N} \left(\frac{\lambda^\alpha}{\mu} \right)^n \left(\frac{1}{(N+n)!} \right) + \left(\frac{\lambda^\alpha}{\mu} \right)^{s-N} \left(\frac{\lambda^\alpha + \lambda^\beta}{\mu} \right)^N \frac{1}{s!} \left(\frac{\left[\frac{\lambda^\alpha}{s\mu} \right]}{1 - \frac{\lambda^\alpha}{s\mu}} \right) \right]^{-1}$$

The average number of packets in the system is $\bar{Q} = \sum_{n=0}^{\infty} n \pi_n$

and the overall average packet delay is $\bar{A} = \dfrac{\bar{Q}}{\lambda^\alpha + \lambda^\beta (1 - P[n \ge M])}$.

The average packet delay for class α is:

$$\bar{A}^\alpha = \sum_{n=0}^{s-1} \frac{\pi_n}{\mu} + \sum_{n=m}^{\infty} \left(\frac{n-s+1}{s\mu} + \frac{1}{\mu} \right) \pi_n .$$

IV. GAME THEORY FORMULATION FOR MULTI-SERVER QUEUEING SYSTEM

Consider l packets arrive to the parallel system which is composed of K multi-server queueing systems according to a Poisson arrival rate λ^t. Φ_i^l is the fraction of class l packets assigned to the multiserver queueing system i and the fraction vector for each class l is $\Phi^l = \left[\ldots \Phi_i^l \ldots \right]$ For example consider two class of packets η *and* κ belongs to l . Therefore the class η wants to minimize its average packet delay thats in queue and the class k packets are blocked and wants to minimize its blocking probability.
Each class must know the cost function and constraints.
Constraint and Cost function for class η is :

$$\text{Minimize } H^\alpha(\Phi^\eta, \Phi^\kappa) = \sum_{i=1}^{K} \Phi_i^\eta \bar{A}_i^\eta$$

with respect to Φ^η such that $\sum_{i=1}^{K} \Phi_i^\eta = 1, \Phi^\eta \ge 0$ for all i and Constraint and Cost function for class κ is :

$$\text{Minimize } H^\alpha(\Phi^{\eta*}, \Phi^\kappa) = \sum_{i=1}^{K} \Phi_i^\kappa P[n_i \ge T_i]$$

with respect to Φ^κ such that $\sum_{i=1}^{K} \Phi_i^\kappa = 1, \Phi_i^\kappa \ge 0$ for all i

V. GRAPHICAL REPRESENTATION

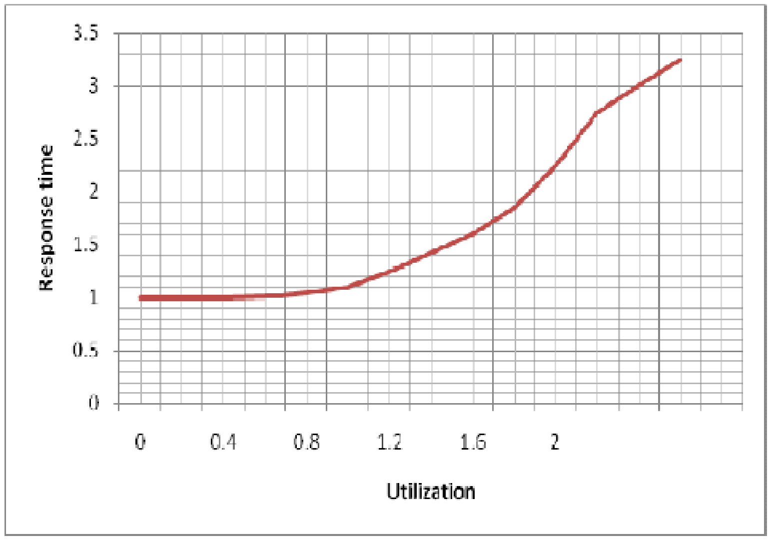


Figure 1

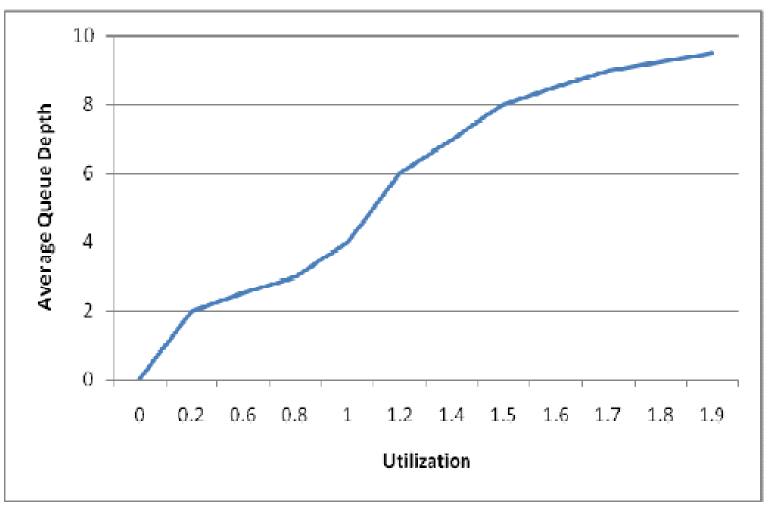


Figure 2

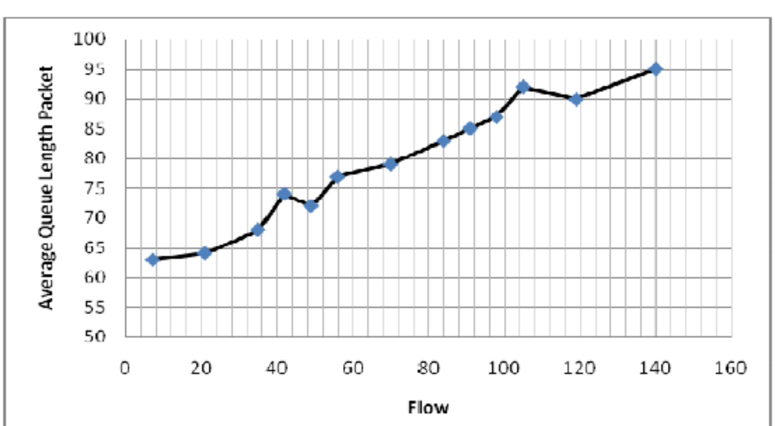


Figure 3

VI. CONCLUSION

In this paper, game theory approach is used in the network routing problem, where one class of packets wants to minimize its average packet delay, while the other class of packets wants to minimize its blocking probability. The several performance measure are found for a multi-server queueing system in which the first class of packets is in queued and the other class is when the number of packets in the system is more than some threshold. Graphical representation shows that various implementation that could support the optimal stream control mechanism in routing algorithm.

References

[1] E.Altman, Stream control mechanism using theory of zero-sum Markov games, *IEEE ransactions on Automatic Control mechanism*, (1994).

[2] S. Andradotir, H. Ayhan and D. Down, Server assignment policies for maximizing the steady state throughput of finite queueing systems, *Management Science*, **47**, (2001), 1421-1439.

[3] D.P. Bertsekas and J.N.Tistsiklis, Parallel and Distributed Computation, (1989), Prentice-Hall.

[4] A.D. Bovopoulos. Resource allocation algorithms for packet switched networks. *Columbia University*, (1989).

[5] W.Ching, S.Choi and M.Huang, Optimal Service Capacities in a Competitive Multiple-Server Queueing Environment, *Proceedings of COMPLEX 2009,Shanghai, Lecture notes of the Institute for Computer Sciences, Social- Informatics and Telecommunication Engineering, Springer*, **4**, (2009).

[6] D.Chlamtac, A. Farago and T.Zhang, Optimizing the system of virtual paths, *IEEE/ACM Trans. On Networking*, **2**, (1994), 581-586.

[7] C.Douligeries and R. Mazumdar. A game theoretic approach to stream control mechanism in an integrated environment with two classes of users. *Proceedings IEEE Computer Networking Symposium*, (1988), 214-221.

[8] A.A. Economicdes and J.A. Silvester. Load sharing , Routing and Congestion control mechanism in distributed computed systems as a Nash Game, *USC Technical Report CENG 90- 06*, (1990).

[9] M.El-Taha and B. Maddah, Allocation of service time in a multi server system, *Management Science*, **52**, (2006) 623-637.

[10] J.Feigenbaum, Games, Complexity Classes and Approximaiton Algorithms, *Proceedings of the International Congrgess of Mathematicians*, **3**, *Documenta Mathematica, Journal Der Deutschen Mathematiker*, (1998).

[11] R.Garg, A game Theoretic Approach Towards Congestion Control mechanism in Communication Networks, ACM SIGCOMM, (2002).

[12] M.T.T. Hsiao and A.A. Lazar .Optimal stream control mechanism of multi-class queueing networks with decentralized information. *Proceedings IEEE Infocom*, **87**. 652-661,(2009).

[13] R. Jain, Congestion Control mechanism in Computer Networks: Issues and trends, *IEEE Network Management*, (1990), 24-30.

[14] Y. Korilis, A.Lazar and A. Orda, Capacity allocation under non-cooperative routing, *IEEE Trans.an Automatic Control mechanism*, **42**, 309-325 (1997).