Performance Study of OBS Combined Node via Mixed Loss Delay Queueing Systems

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ABSTRACT

In this paper, we present a performance study of OBS (Optical Burst Switched) combined node via mixed loss delay queueing models. In an OBS network, a node combining both edge and core switching functions multiplex the local traffic with the transit traffic on the output wavelengths channels. To control the channel sharing, strategies are proposed and analyzed in this study by extending the basic mixed loss delay queueing models. The presented models are solved by Markov chain techniques and the results are compared, and where necessary also supported, by the simulations of an OBS node implemented in detail.

Key Words: **Mixed Loss Delay System, Queueing Model, Optical Burst Switched Combined Mode, Local Traffic, Transit Traffic, Markov Chain Analysis.**

1. INTRODUCTION

Since the paradigm of OBS was introduced over a decade ago, its performance evaluation received a considerable attention which persists as of today. Clearly, before full optical packet switching is technically realized, OBS will remain the most reasonable option to facilitate the statistical multiplexing over WDM. Mechanisms and functionalities considered in OBS for packet traffic burstification and for burst contention resolution provide novel and interesting scenarios for stochastic modelling. There exist already vast literatures devoted to burst assembly, optical delay lines, wavelength conversion or burst dropping strategies. Due to the system complexity, these mechanisms are usually investigated separately to determine their individual impact on burst delay and loss characteristics. Their joint performance and full inter-action are usually hard to evaluate in an analytical way and must be examined by simulations.

In a prevalent number of these studies, it is taken for granted that an OBS network is strictly divided into the edge and the core part. This means that the network consists of the nodes only assembling packet traffic into bursts (edge nodes) and the nodes only switching the burst traffic along the transmission path (core nodes) as shown in Fig. 1(a). However, this assumption cannot be valid for practical future deployments in dynamically reconfigurable networks with mesh topology. In these networks, not only a few but probably majority of the nodes will have to combine both functionalities to provide flexible operation, as shown in Fig. 1(b). Such nodes are referred as combined OBS nodes. A significant challenge in their design is that the local traffic must be multiplexed on output wavelengths channels with the transit traffic cutting through the node and a mechanism is needed to control the channel sharing. Otherwise, a high local load may cause high losses of the

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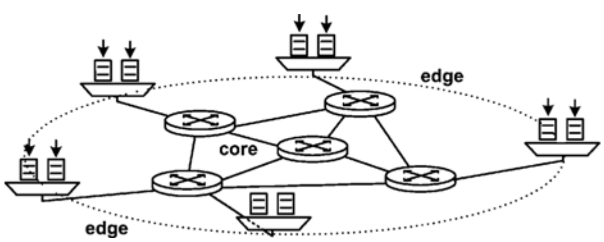
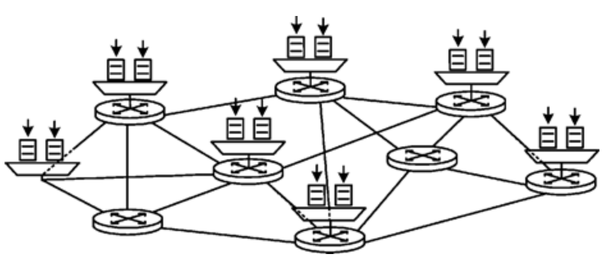
external traffic and, vice versa, too intensive transit traffic may greatly delay the transmission of locally assembled bursts. Both phenomena degrade performance of OBS. However, the increase of losses for the transit traffic is expected to have more adverse effects. Bursts that are lost not only waste the reserved path bandwidth but also invoke the retransmission and reordering delays in higher network layers. These effects are well-documented in numerous studies on Transmission Control Protocol over OBS, see for example [1-3] and references therein. On the contrary, waiting in the transmission buffer, even when excessive, is easier to monitor and does not propagate out of OBS layer to such an extent, thus assuring more stability to particular end-to-end packet flows. Therefore, when contention for the channels occurs, transit traffic should be prioritized with no doubt. To the best of our knowledge, the issue of multiplexing of local and transit traffic in OBS has not been a subject of analytical treatments. In several simulation studies, this fact was indeed assumed, however its influence on the final results was not discussed [4-7]. From the theoretical viewpoint, the combined node can be modelled as a MLD (Mixed Loss Delay) queueing system. This class of queues has the common feature that a pool



(a) SEPARATION OF EDGE AND CORE PARTS



(b) COMBINED NODE

FIG. 1. OBS NETWORK

of servers handles two streams of arrivals, called delay and non-delay customers. Upon finding all the servers busy, the non-delay customers are immediately lost and the delay ones are queued to wait for the service. These systems, in different variants, have found application in modelling networks nodes with integrated data and voice transmission.

In this paper, we apply the mixed loss delay systems with certain extensions in context of OBS. More specifically, we analyze performance of two threshold-based strategies giving priority to the transit traffic on a single output link. They are described in detail along with the node architecture in Section 2. Our goal is to investigate the blocking and waiting characteristics associated with these strategies for a given load and system capacity.

Unfortunately, even for purely Poissonian conditions, analytical solutions regarding the MDL systems with priorities are not easy to use and for finite queues no studies have been conducted. Thus, we develop our own analysis based on the continuous-time Markov chains, in which we take into account also the blocking probability of the burst transmission queue as it may be important in practical dimensioning. The system state equations are solved by numerical computation. The obtained results are compared with simulations of a combined node implemented with details of assembly and scheduling on a customized OBS simulator. For the sake of completeness, we review also analytical results scattered in the literature as they could serve as a quick check in special cases and a reference in view of further research. The rest of the paper is organized as follows. In Section 2, architecture of the OBS combined node is presented and the way it handles the traffic is explained. Section 3 surveys MLD systems considered in the queueing theory literature. In Section 4, our models for threshold-based priority described and their analysis is provided. The analytical and simulative results are discussed in Section 5 and Section 6 concludes the paper.

2. OBS COMBINED NODE

Block diagram of a combined node is shown in Fig. 2(a). Packets arriving from different sources are classified according to their destination address and distributed among corresponding assembly queues. Subsequently, they are assembled into the bursts using time, length or hybrid method and forwarded to the BTQs (Burst Transmission Queues) after the routing decision. Each BTQ is associated with one output link comprising c wavelength channels. Then, the scheduling module looks for a free channel, and if available, it sends a burst control packet to the destination node. Subsequently, the burst is forwarded from BTQ to the scheduler buffer. In the scheduler buffer, the burst waits until its transmission starts in optical domain. At the same time, the transit traffic is handled. BCPs (Burst Control Packets) signalizing the incoming bursts arrive at the routing module. If the destination of a burst is the current node, the burst is disassembled. However, if the burst is to reach another node, the information is sent to the scheduling module that looks for a free channel at the desired output link. If the channel is found, possibly with the need of wavelength conversion, the burst is forwarded. Otherwise, the considered burst is dropped and lost.

As already mentioned in Section 1, to prevent from overall performance degradation the transit traffic should be prioritized to some extent over the local one while multiplexing on a single link. The two following priority schemes, depicted in Fig. 2(b), can be applied.

2.1 LUT (Local Usage Threshold) Based Scheme

In this scheme, the local traffic is allowed to occupy not more than a threshold, k, of c channels. When this threshold is reached, the transmission of bursts waiting in BTQ is stopped. The transit traffic can use the channels without any limit.

In this scheme, the transit traffic can use all the c the channels without any limit whereas the local one is allowed to occupy not more than k of them. When this threshold is reached, the transmission of bursts waiting in BTQ is stopped.

2.2 TUT (Total Usage Threshold) Based Scheme

This scheme assumes, that transmission of local bursts is stopped when local and transit bursts in total occupy k or more channels. Here we distinguish two options.

2.3 Preemptive

If an incoming transit burst is accepted above the threshold, k, but there are already scheduled local bursts in the system, one of them is preempted. The preempted

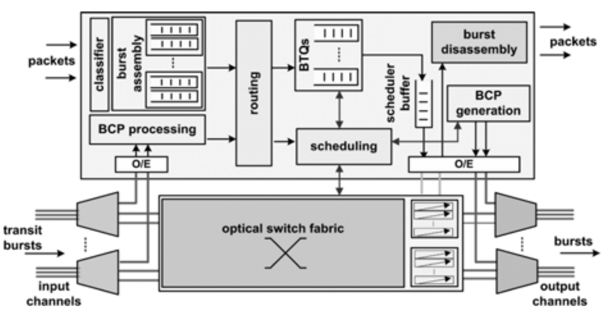


FIG. 2(a). ARCHITECTURE OF THE OBS COMBINED NODE

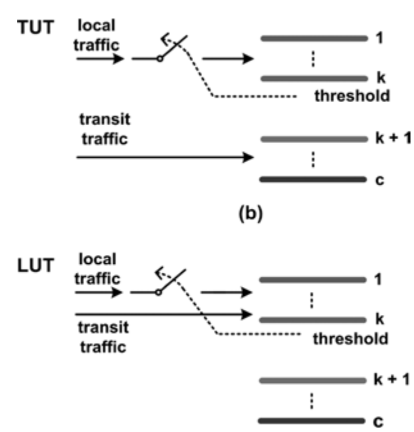


FIG. 2(b). TWO THRESHOLD BASED STRATEGIES FOR PRIOPRITISATION OF THE TRANSIT TRAFFIC burst is pushed back to the front of the BTQ and rescheduled. If the BTQ is full, the burst is dropped.

2.4 Non-Preemptive

Transit bursts accepted above the threshold cannot preempt the local ones.

3. MIXED LOSS DELAY SYSTEMS

In this section, we briefly discuss MLD queueing systems along with the solutions available in literature. A simplest MLD system assumes two Poisson arrival streams for non-delay and delay customers with different rates λ_1 and λ_2 respectively, a group of c exponential servers with rate μ common for both streams and an infinite waiting room. The offered load of both streams is $\rho_1=\lambda_1/\mu$ and $\rho_2=\rho_2/\mu$ respectively. Cohen analyzed this system in 1956 and gave explicit solutions for the probability of the number of customers present in the system and the waiting time distribution [8]. In particular, the probability of blocking of the loss customers is:

$$P_B^{(1)} = \frac{cE_c(\rho)}{c-\rho_2+\rho_2 E_c(\rho)} \tag{1}$$

where $\rho=\rho_1+\rho_2$

and $E_c(\rho)$ is the standard Erlang loss formula:

$$E_c(\rho) = \frac{\rho^c}{c!} \Bigg/ \sum_{i=0}^{c} \frac{\rho^i}{i!}$$

The mean waiting time of the delay customers accepted to the queue is:

$$E[T_W] = \frac{1-c+\rho_1}{\mu(c-\rho_1)} \tag{2}$$

Quite recently, Takagi [20] published relevant formulas for blocking probabilities for a finite system with s places in the queue:

$$P_B^{(1)} = p_c.\rho_1^s \tag{3}$$

$$P_B^{(2)} = p_c \frac{1-\rho_1^{s+1}}{1-\rho_1} \tag{4}$$

where p_c is the probability that all the c servers are occupied and given by:

$$p_c = \frac{a^c/c!}{\sum_{i=0}^{c} \frac{a^i}{i!} \frac{a^c \; \rho_2/c \left[1-(\rho_2/c)^s\right]}{1-\rho_2/c}} \tag{5}$$

with $\alpha=(\lambda_1+\lambda_2)/c$

Unfortunately, closed-form solutions do not exist if the system gets somewhat more complicated. For example, for an infinite queue but two different service rates, μ_1 and μ_2, there is a procedure due to Pratt [9] which is, however, computationally impractical for larger number of servers. Approximate results in this case have been proposed by Bhat and Fisher [10]. Takahashi and Katayama [11] have analyzed Cohen's system with batch arrivals, obtaining probability generating function of steady-state probabilities, the number in the system and Laplace-Stieltjes transform of waiting time. In [12] Takahashi generalizes the model to arbitrary distributed renewal arrivals and services, whereby exact solutions for the mean waiting time and blocking probability are possible only for Poisson arrivals and one server. For other cases, a diffusion approximation is derived. Other types of approximations for non-batch arrivals are derived by Akimaru, et. al. [13] by classical transform methods. In that model, either delay or non-delay input is assumed to be renewal. Approximation comes from the fact that superposition of Poisson and renewal processes is assumed to be still renewal. Most recently, Ozaki and Takagi [14] studied purely Markovian finite system with state-dependent arrival rates. Here, the calculation of state probabilities requires numerical solution of state equations and for Laplace transform of waiting time distribution a recursive formula is given. Control schemes based on preemptive and non-preemptive prioritisation were studied exclusively by resorting to matrix analytical methods for an infinite system in [15-16] in context of ATM (Asynchronous Transfer Mode). Presentation of some of these models can be found in handbooks [17-19].

4. ANALYTICAL MODELLING

Considering a single output link with c channels in an OBS node shown in Fig 3. The multiplexing of local and transit traffic is required on the link. The system can be mapped to a standard MLD queueing model as shown in Fig. 3, where the servers correspond to the wavelength channels. The local traffic is buffered in the burst transmission queue if it cannot occupy the channels directly. While the transit traffic arriving as a non-delay traffic only occupy the channels directly if available. Additionally, a switch shown in Fig. 3 is used to restrict the access of locally assembled traffic to limit the loss rate of the transit traffic. Different strategies to be used for this purpose are LUT and TUT as described in Section. 2. In this section, we first briefly discuss the nature of both types of traffic along with some simulation results. Secondly, the behavior of a single link under the transit traffic is analyzed again using simulations. The Markov chains are then used to model the behavior of underlying MLD systems employing the above mentioned schemes.

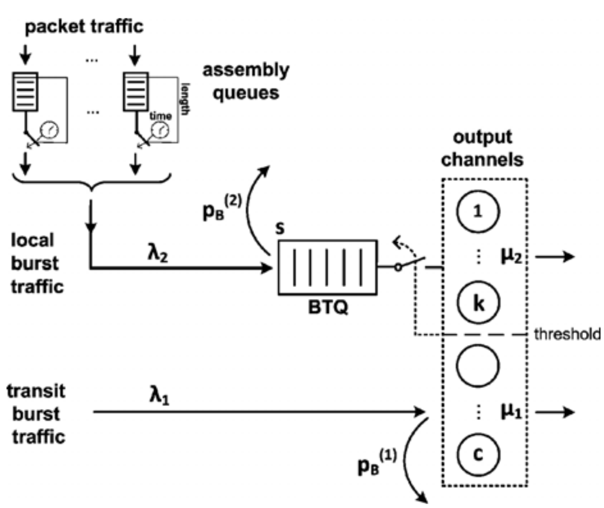


FIG. 3. MIXED LOSS DELAY QUEUEING MODEL FOR A SINGLE OUTPUT PORT OF THE OBS COMBINED NODE

The local traffic is generated typically by an aggregate output process from a number of burst assembly queues. The output process of each individual assembly queue is renewal [20]. It has been proven by [19] that if many renewal processes are aggregated, the combined process is distributed exponentially if the aggregated processes approach to infinity in number. This assumption is valid practically in the case of an OBS assembler. It can be observed from the simulated results shown in Fig. 4 where the pdf of burst inter-departure times from an aggregate of assembly queues have been plotted. Assembly queues are varying from one to ten. It is clear that even combining output of a small number of queues for example three only, leads to an output process having a negative exponential distribution. The burst transmission queue shown in Fig. 4 therefore, is fed by a Poisson load. The same assumption is true for the transit traffic by extending the comment for a bigger network, where the traffic is being generated independently in all nodes over the whole network.

For the behavior of an output link under transit traffic only, a simulation study has been performed. Negative exponentially distributed burst lengths and inter-arrival times have been assumed. The channel scheduling algorithm used is LAUC-VF (Latest Available Unused Channels with Void Filling) [21]. It can be recognized by comparing the burst blocking probability with the Erlang-B loss formula that a single OBS link offered with transit

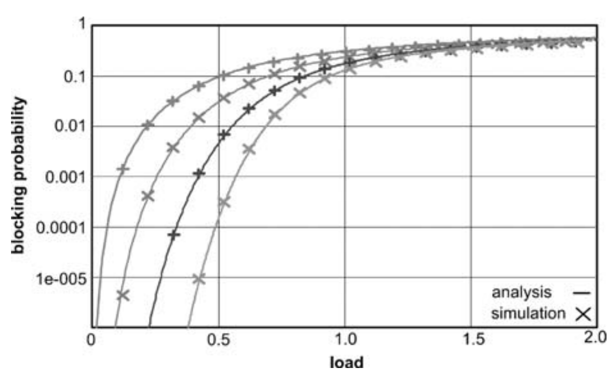


FIG. 4. BLOCKING PROBABILITY OF A SINGLE WDM LINK IN AN OBS NETWORK VERSUS THE OFFERED LOAD: DOMPARISON WITH ERLANG-B LOSS FORMULA

traffic only behaves as a pure loss system. These assumptions help us to use the traditional Markovian loss delay systems to model the behavior of an output link in a combined OBS node shown in Fig. 3. We start our analysis by assuming the basic MLD system where no threshold is enforced for both types of traffic entering the system. It means that the system behaves as a full-access system both for local and transit traffic. The number of wavelength channels are c and a finite queue of size s is available to buffer the local traffic. The behavior of system can be described with the help of a state transition diagram as shown in Fig. 5 for an example M/M/n/S system. The number of servers n taken are three and the system size including the waiting places (S) equals five. The state transition diagram is a CTMC (Continuous Time Markov Chain). A state in the CTMC is described by the parameters (x_1,x_2,x_3).

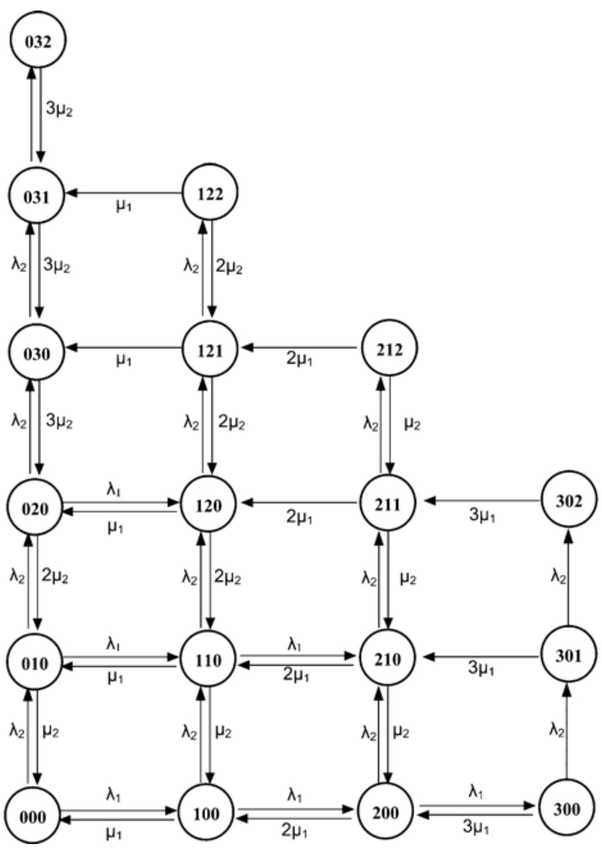


FIG. 5. STATE DIAGRAM OF A AN EXAMPLE M/M/N/S MIXED LOSS DELAY SYSTEM WITH NO THRESHOLDS WHERE N=3, S=5

where $x_1:(0<x_1<c)$ is the number of busy channels by the transit traffic, $x_2:(0<x_2<c)$ is the number of busy channels by the local traffic, $x_3:(0<x_3< s)$ is the number of local bursts in the waiting queue. This model has been solved numerically for the blocking and waiting probabilities and also for the mean waiting time in [22].

The model described above can be extended easily with LUT based scheme. In this scheme, at any time t, the local traffic can occupy a maximum number of channels equal to the threshold. After reaching this maximum number, the local traffic is not allowed to occupy more channels and is forced to wait in the BTQ if not full. The state diagram shown in Fig. 6 is used to describe the behavior of such system. Fig. 6 is drawn for an example M/M/n/S system with n=4, S=7. The threshold k is taken as two. Hence, if two servers are occupied by the local traffic, no more local bursts are allowed to get the service and have to wait in the waiting queue. This can be observed from a transition: (1,2,0) to (1,2,1).

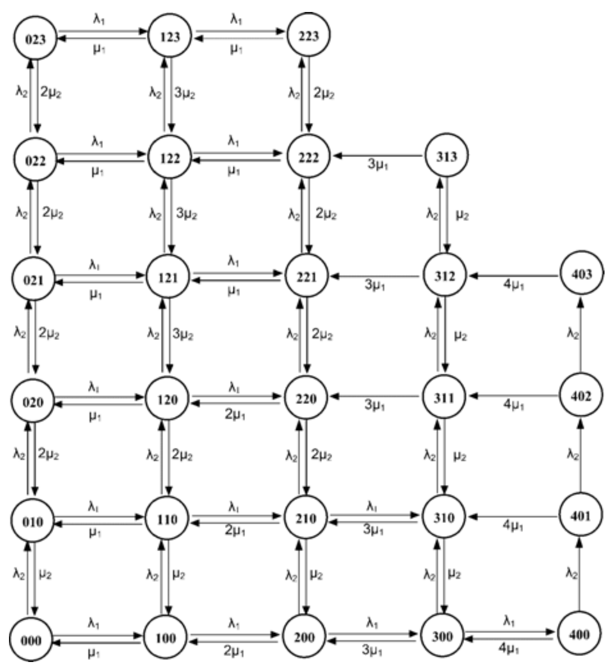


FIG. 6. STATE DIAGRAM OF AN EXAMPLE M/M/N/S MIXED LOSS DEALY SYSTEM WITH LOCAL USAGE BASED THRESHOLD OLD (K) WHERE N=4, S=7, AND K=2

For the solution of such Markov chain, the probabilities of states can be expressed in the form of a vector.

$p = [p_0.p_1.p_2,...]$

Now the matrix defining all transition rates between different states called a transition rate matrix **Q** is developed. Using the transition rate matrix, the system in steady state can be expressed in matrix notation as given:

$$pQ = 0 \tag{6}$$

which is a compact form for the set of balance equations. It can then be solved using different methods of solving set of linear equations. For a simple system with one dimensional state diagram, we can solve system iteratively solving equations. However, for systems having multi-dimensional state diagrams, numerical solutions are used. Many robust techniques are available for such solutions. In addition, these techniques can be programmed to find the solution in an efficient manner. The selection of a suitable method from the large number of available methods is important as the method used must be fast, and they should require little storage and must numerically stable. We have used a method by Richardson [23] which is known as successive over-relaxation method.

The state probabilities have been calculated which are used to find the expressions for the blocking probability of local and transit traffic. The blocking probability of transit traffic $P_b^{(1)}$ can be found by summing up the state probabilities showing all servers busy, hence no more transit burst can enter the system. The sum can be expressed as:

$$P_b^{(1)} = \sum_{x_1=c-k}^{c} \sum_{x_3=0}^{s} p\left(x_1, c-x_1, x_3\right) \tag{7}$$

The blocking probability of local traffic $P_b^{(2)}$ can be found by summing up the state probabilities where not only all servers are busy but also there is no waiting places in the BTQ as given by:

$$P_b^{(2)} = \sum_{x_1=0}^{c-k} p\left(x_1, c-k, s\right) + \sum_{x_1=c-k+1}^{c} p\left(x_1, c-x_1, s\right) \tag{8}$$

The waiting probability for the accepted local traffic can also be easily found also using the state diagram. An important measure is the mean waiting time. For the mean waiting time, in contrast to the authors in [22], we use the Little law:

$$E\left[T_w\right] = \lambda\left(1 - P_b^{(2)}\right)E\left[Q\right]$$

with a modified arrival rate:

$$\lambda\left(1 - P_b^{(2)}\right)$$

The Little law relates the mean waiting time to the mean queue size independent of what type of service is offered to the incoming customers. If the blocking offered to the customers being queued is known, Little's law can be used readily. This has been validated by the simulative results which are in perfect match with the results from the Markov chain and will be discussed in Section. 5.

In TUT based scheme the local traffic is allowed to occupy the channels until a specific number of channels are busy no matter by the local or transit traffic. Additionally, we have to clearly define the behavior of system if an incoming transit burst is accepted above the threshold k due to the availability of wavelength channels. There are two possibilities. Firstly, if there are already scheduled local bursts in the system, one of them can be preempted to fulfill the threshold criterion. In this scheme, the preempted burst is pushed back to the front of the BTQ and rescheduled. If the BTQ is full, the burst is simply dropped. As a second possibility, the already scheduled local bursts are not allowed be preempted. In an OBS network, both schemes are applicable due to an in-advance scheduling of the incoming bursts. We analyze both type of strategies using Markov chains.

The first system can be analyzed by a Markov chain for an example M/M/n/S system with n=3 and S=7, which is small but good for the clarity of understanding. The state diagram has been shown in Fig. 7. The parameters used to describe a state are the same as before. The preemption is done for example when the system is in the state (0,2,1) and a transit burst arrives. In this state, no channel is busy in transmitting a transit burst and two channels are busy transmitting the local bursts. Additionally, there is one local burst waiting in the queue. Now if a transit burst arrives, it can be scheduled because of the availability of a free channel, however, due to the threshold criterion, a locally scheduled burst should be preempted from the system. This is shown by the transition from (0,2,1) to (1,2,2). The preempted local burst is pushed back to the front of waiting queue. However, the preempted burst is dropped if the queue is full. This can be observed from the transitions: (0,2,3) to (1,1,3) and (1,1,3) to (2,0,3). The expressions for the blocking probability of local and transit traffic can also be calculated as before and expressed by:

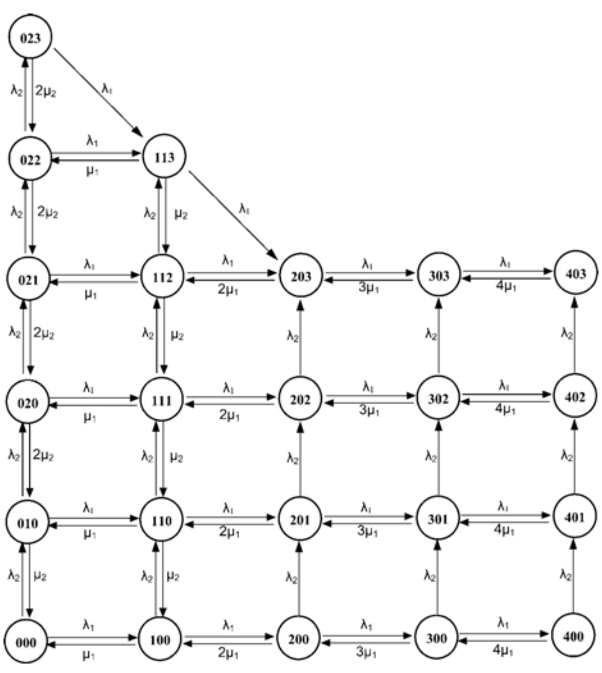


FIG. 7. STATE DIAGRAM OF AN EXAMPLE M/M/N/S MIXED LOSS DEALY SYSTEM WITH TOTAL USAGE BASED THRESHOLD OLD (K) AND PREEMPTION OF LOCAL TRAFFIC WHERE N=4, S=7, AND K=3

$$P_b^{(1)} = \sum_{x_3=0}^{s} p(c,0,x_3), \quad \text{k < c} \tag{9}$$

$$P_b^{(2)} = \sum_{x_1=0}^{c-k} p(x_1, c-k, s) + \sum_{x_1=c-k+1}^{c} p(x_1, 0, s), \quad \text{k < c} \tag{10}$$

The waiting probability for the local traffic can also be easily found using the state diagram.

The second system with no preemption is described again by a Markov chain for an example M/M/n/S system with n=4, S=7 and k=2, for the sake of uniformity. The state diagram has been shown in Fig. 8. The parameters used to describe a system state are the same as before. In this system, if a transit burst arrives above the threshold and a channel is free to serve it, it is accepted with out preemption of an already scheduled local burst. Although, accepting it may increase the total number of bursts in the system above the predefined threshold. This can be explained from an example transition from (0,2,3) to (1,2,3), where the number of busy servers are equal to the threshold k but a transit burst is accepted without preemption of any of the local burst.

The expression for the blocking probability of local traffic is given as:

$$P_b^{(1)} = \sum_{x_1=c-k}^{c} \sum_{x_3=0}^{s} p(x_1, c-x_1, x_3) \tag{11}$$

The blocking probability of transit traffic can also be found in the same way. Little's law is still valid and can be applied readily.

5. RESULTS

In this section, we present some numerical results to show the behavior of studied systems. All the results have been validated with the extensive simulations. Different systems have also been analyzed for their advantages and disadvantages in comparison with each other. Results are also presented to show the behavior of the systems with respect to varying thresholds and to describe the relationship between the blocking probability of transit traffic and the mean waiting time of local traffic. For all the plots, the number of channels taken equals sixteen and there are ten waiting places in the queue.

In Fig. 9 the blocking probability of local traffic is plotted versus arrival rate of local traffic. The transit load is fixed and we analyze the scheme based on local usage based threshold. For different curves varying the thresholds from four to sixteen have been used. It can be seen that with the increase in threshold value, the blocking of local traffic decreases and for k=16, both traffic have equal priorities. Fig. 10 depicts the same trend, where mean waiting time of local traffic in the queue is plotted using the same parameters. In Fig. 11, the blocking probability of transit traffic is shown also for LUT. It is clear that the blocking probability increases upto a certain point and then saturates. The saturation point depends upon the threshold

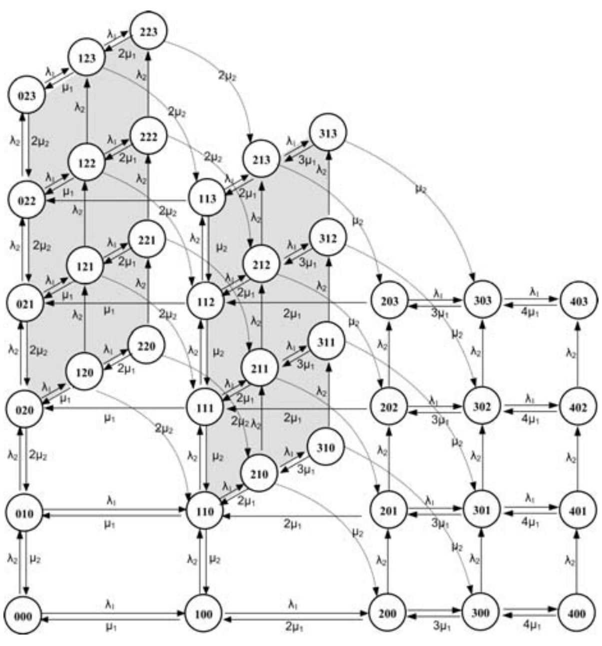


FIG. 8. STATE DIAGRAM OF AN EXAMPLE M/M/N/S MIXED LOSS DEALY SYSTEM WITH TOTAL USAGE BASED THRESHOLD OLD (K) WITHOUT PREEMPTION OF LOCAL TRAFFIC WHERE N=4, S=7, AND K=2

for local traffic. If the threshold equals 16, the system behaves as full-accessible system for local traffic and the blocking of transit increases with the increase in the local traffic load. The three systems have been compared for the local and transit blocking and the mean waiting time in

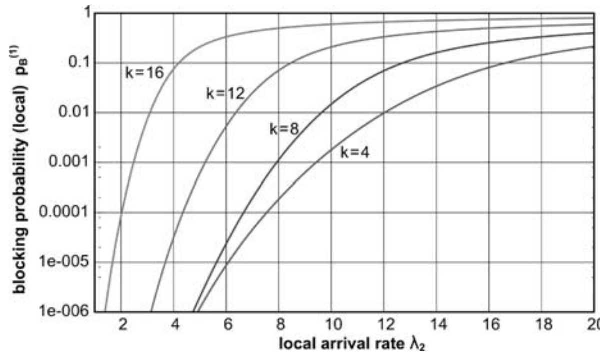


FIG. 9. LUT BLOCKING PROBABILITY OF LOCAL TRAFFIC WITH VARYING THRESHOLDS OF 4.8.12.16 WITH TRANSIT LOAD = 10, W=16, S=10

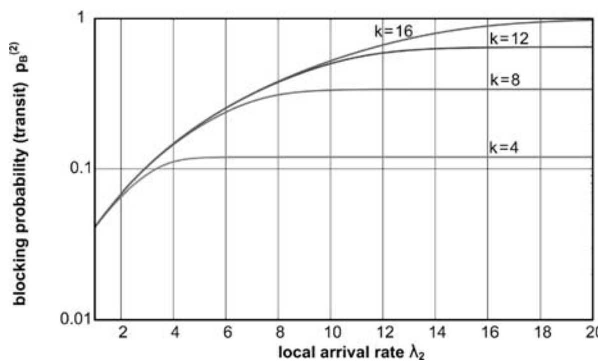


FIG. 10. LUT BLOCKING PROBABILITY OF LOCAL TRAFFIC WITH VARYING THRESHOLDS OF 4.8.12.16 WITH TRANSIT LOAD = 10, W=16, S=10

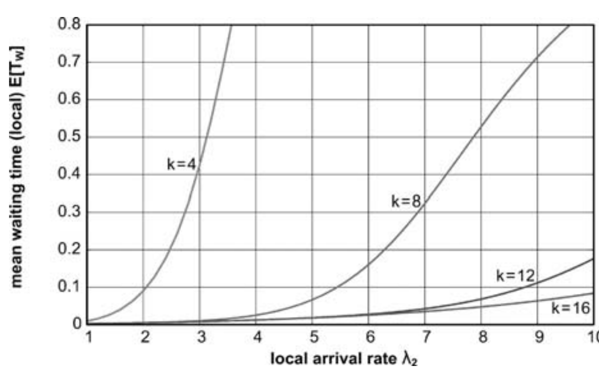


FIG. 11. LUT MEAN WAITING TIME LOCAL TRAFFIC WITH WITH VARYING THRESHOLDS OF 4.8.12.16 WITH TRANSIT LOAD = 10, W=16, S=10

Figs. 12-14. For fair comparison, arrival rates of both traffic have been increased simultaneously with a threshold of fifty percent of the total number of channels. It can be observed that in case of delay traffic, LUT scheme gives the least blocking and the same is true for the mean waiting time. While TUT with preemption leads to the highest blocking rate for local traffic. The reverse is true for the loss rate of transit traffic. This phenomenon is more clear in the Figs. 15-16 where the relationship between the waiting time of local traffic and the blocking behavior of transit traffic is shown under varying threshold values. The behavior of two strategies local usage based threshold and total usage based threshold with out preemption has been analyzed. It is clear that with the decrease in threshold value the transit traffic gets less blocking, however, the mean waiting time of the local traffic is negatively effected for both strategies. The results can be used to find a threshold value required for a particular loss rate of the transit traffic or the mean waiting time for the local traffic.

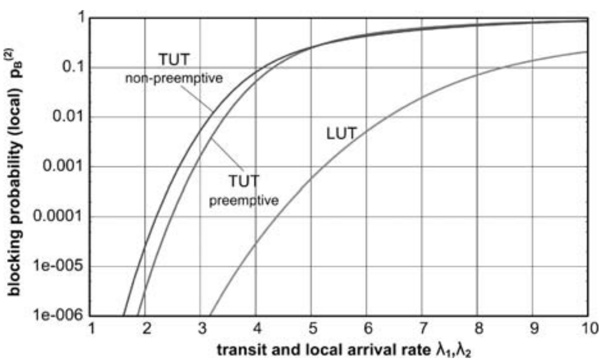


FIG. 12. LUT VERSUS TUT BLOCKING OF DELAY TRAFFIC VERSUS BOTH ARRIVAL RATES λ_2 AND λ_2

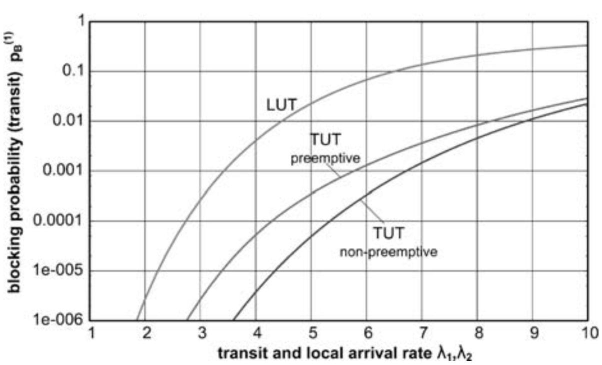


FIG. 13. LUT VERSUS TUT BLOCKING OF LOSS TRAFFIC VERSUS BOTH ARRIVAL RATES λ_2 AND λ_2

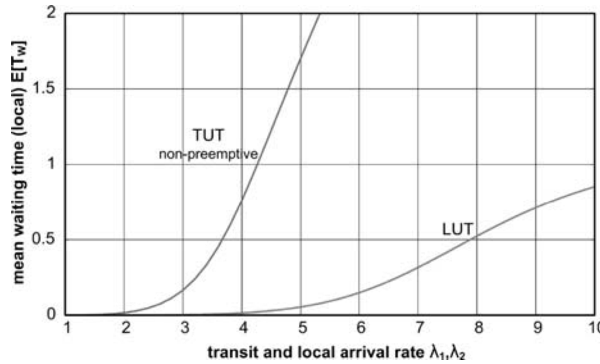


FIG. 14. MEAN WAITING TIME OF DELAY TRAFFIC VERSUS BOTH ARRIVAL RATES λ_2 AND λ_2

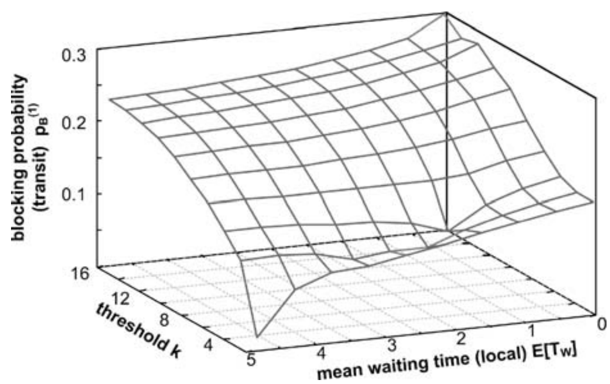


FIG. 15. LUT VERSUS TUT MEAN WAITING TRIME OF DELAY TRAFFIC VERSUS BLOCKING PROBABILITY OF LOSS TRAFFIC WITH VARYING LOCAL THRESHOLED

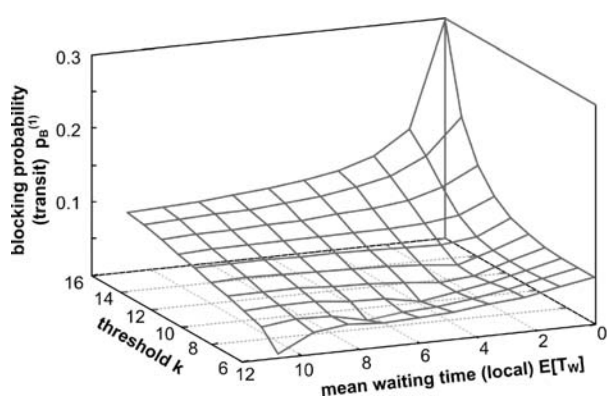


FIG. 16. LUT VERSUS TUT MEAN WAITING TRIME OF DELAY TRAFFIC VERSUS BLOCKING PROBABILITY OF LOSS TRAFFIC WITH VARYING OVERALL THRESHOLED

6. CONCLUSIONS

We have analyzed a combined OBS node using mixed loss delay queueing models. Three different strategies have been discussed in the context of OBS, where priority is given to the transit traffic as compared to the local traffic. Models have been developed and analyzed for presented schemes. Markov chain based techniques are found to be very useful for a fair comparison among the models analyzed. The results show, that a restricted access of the local traffic can be used to achieve a bargain between the mean waiting time of local traffic and the loss rate of transit traffic.

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