

Quality of Service and Performance Evaluation of Congestion Control for Multimedia Networking

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ABSTRACT—The most important components of multimedia networking are video streaming and synchronization. In video networking, the frames are split into smaller packets at the application layer. The packets of a frame are assembled before being processed at the receiver. For real-time video streaming, packet acknowledgments and retransmission are not practical. When congestion occurs, some packets may be dropped. Consequently, the entire frame (and sometimes successive frames in a group) is considered lost (i.e., not displayable). Often a loss of one packet from the frame can lead to a loss of the whole frame. Selective Message Discarding Policies have been proposed to reduce or avoid congestion and achieve a better buffer utilization by discarding all packets that do not belong to good messages. In this paper, these discarding policies are studied and applied for MPEG video data transmission. Our queuing analysis for video data yields explicit (closed form) expressions for the average buffer occupancy and loss probability by using Early Message Discard and Partial Message Discard policies. The quality of service (QoS) has been studied and evaluated based on a frame (or a group of frames) instead of a packet. The results for different arrival rates, service times, and frame sizes are presented.

KEYWORDS—Average buffer occupancy, loss probability, EMD and PMD polices, packet model.

I. INTRODUCTION

Quality of service (QoS) is one of the major goals to be achieved in multimedia networks. The quality of service is not measured as a parameter of number of packets that are successfully delivered but rather as the number of successful frames that are displayed. In real-time video streaming applications, frames are segmented into smaller fixed or variable size packets which are then transmitted by the network. For any frame to be useful, all of its packets should arrive successfully at the other destination side. Waiting for packet acknowledgments and retransmission are not practical for real-time streaming applications. In compressed video data streaming, there is a dependency of data within a frame as well dependency among frames. Therefore, successful delivery of the frames is very important. To provide a proper presentation, both the buffer underflows and overflows need to be avoided.

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We start with the memoryless M/M/1/N model using continuous-time Markov model. Basically M/M/1/N refers to negative exponential arrivals and service times of packets (i.e. generated by a Poisson process) with a single server and a finite buffer size (N). The frame size is considered to be geometrically distributed. In any practical network element system (like router or switch), buffers are required to absorb the variable processing delays of the network element. If the buffer overflows, all those incoming packets that cannot find a space to reside in will be discarded (dropped). These packets are considered to be lost. Figure 1 shows a network element system.

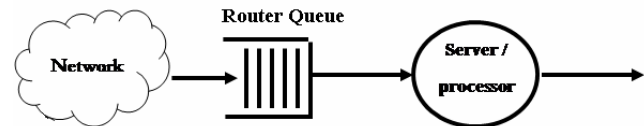


Figure 1. A network element system with a finite buffer.

Selective discarding policies are proposed to reduce or avoid congestion [3] [4] [10]. There are two well-known selective discarding policies: partial message discard (PMD) [7] and early message discard (EMD) [8]. In the previous research, these discarding policies are applied for document messages, email messages, or any arbitrary file. In this paper, we applied these discarding polices for MPEG video data transmission. In PMD policy, the packets of corrupted frames are no longer stored in the buffer [5]. If there is a buffer overflow, an upcoming packet is discarded [5]. Moreover, once a packet of a frame is discarded, the rest of the packets of the frame are also discarded since it is not possible to recover the frame if any of its packets are lost.

EMD policy is a preventive method. When the system reaches a point where it is doubtful to store all the packets of a frame, it discards all the packets of that frame. This is maintained by a threshold that corresponds to the buffer occupancy. If the buffer occupancy is above a threshold, all the incoming packets are discarded till the buffer occupancy goes below the threshold. Even the buffer occupancy goes below threshold, the packets of a frame will not be stored in the buffer if at least one of its packets is lost or discarded. In EMD, it is possible to discard a complete frame due to the threshold. In PMD, only the upcoming packets are discarded after discarding a packet of the frame.

In this paper, we study and analyze the Markovian and memoryless model (M/M/1/N) that supports both discarding

$$Q_1 = \rho(r(1-t\rho)+t)-1+(1-r)(1-\rho^{-N}t) \quad (62)$$

$$F_2 = \sum_{j=1}^N \frac{j \times t_1^{j-1} Q_2 \left[1 - \left(\frac{t_1}{\rho} \right)^{N-j+1} \right]}{(\rho - t_1) Q_1} \quad (63)$$

$$Q_2 = r^2 \rho^2 (\rho - 1) - \rho^2 (r\rho - 1) - q\rho \quad (64)$$

Loss probability for PMD policy can be expressed by $P_{N,0}$, from (61) and (62) we can get:

$$P_{loss} = P_{N,0} = \frac{(1-\rho)tq[r\rho-1]}{Q_1(1+(1-r)\rho)} \quad (65)$$

Our result of $P_{N,0}$ is confirmed with [7].

Average buffer occupancy for M/M/1/N without control can be derived as [9]:

$$ABO = \frac{\rho}{\rho-1} - \frac{(N+1)\rho^{N+1}}{1-\rho^{N+1}} \quad (66)$$

Loss probability for M/M/1/N without control can be expressed by the following equation [9]:

$$P_{loss} = P_{N,0} = \frac{(1-\rho)\rho^N}{1-\rho^{N+1}} \quad (67)$$

V. ANALYTICAL RESULTS

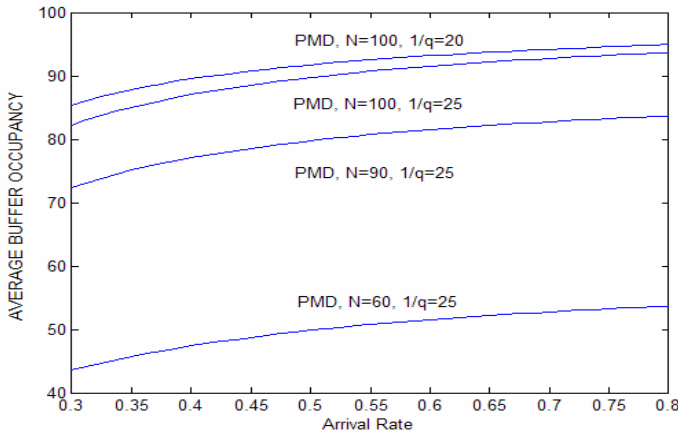


Figure 4: Average buffer occupancy versus arrival rate (service rate = 0.2; N = 60, 90, 100; 1/q = 20, 25)

Figure 4 illustrates the average buffer occupancy versus arrival rate for the PMD policy. It can be shown from Figure 4 for a fixed mean frame length ($1/q$) and traffic load (λ/μ), the increase of ABO as buffer capacity (N) increases. This is expected since there is a high traffic on the network element system ($\text{load} > 1$) and there is a high probability for the arriving packets to be dropped. For a fixed buffer capacity and mean frame length ($1/q$), the increase of ABO as arrival rate increases is also noticed, increasing in arrival rate for a fixed service rate means getting high traffic load. For a fixed buffer

capacity and traffic load, the increase of ABO as mean frame length decreases is noticed. That is to be expected since mean frame length = $1/q$, when the mean frame length decreases, this means there is a higher probability for any head-of-frame packet to arrive.

Figure 5 shows the average buffer occupancy versus arrival rate for PMD policy, through this Figure and Figure 7, for a fixed buffer capacity, mean frame length, and traffic load we can notice that the ABO is lower in EMD than PMD for the given different threshold buffer occupancy levels.

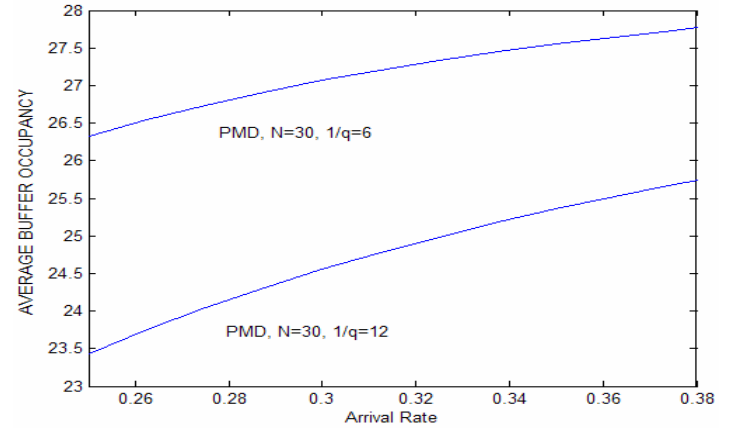


Figure 5: Average buffer occupancy versus arrival rate (service rate = 0.13; N = 30; 1/q = 6, 12)

Figure 6 shows the average buffer occupancy versus arrival rate without applying any discarding policy. Notice the difference between Figures 6 and 4 for the same traffic load and buffer capacity. Figure 7 illustrates the average buffer occupancy versus arrival rate for the EMD policy. For a fixed buffer capacity and threshold buffer occupancy level, the increase of ABO as mean frame length decreases is noticed. It is also shown for a fixed buffer capacity and mean frame length, the increase of ABO as threshold buffer occupancy level increases. This is expected also since there is a high traffic ($\text{load} > 1$).

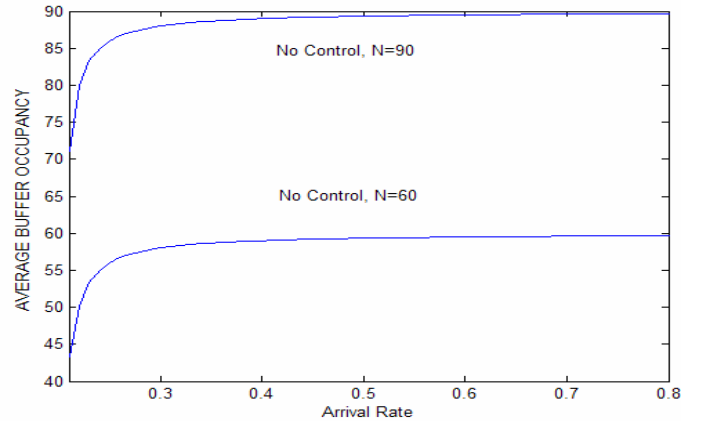


Figure 6: Average buffer occupancy versus arrival rate (service rate = 0.2; N = 60, 90)

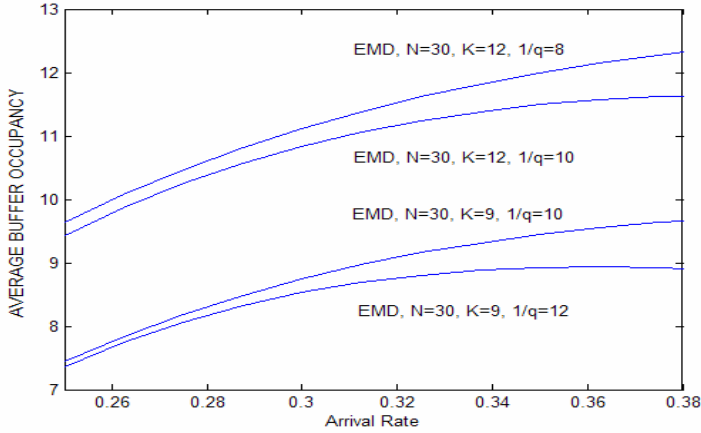


Figure 7: Average buffer occupancy versus arrival rate (service rate = 0.13; N = 30; 1/q = 8, 10, 12; K = 9, 12)

Figure 8 illustrates the loss probability versus buffer capacity for the PMD policy. It can be shown for a fixed service rate and mean frame length that the loss probability decreases as arrival rate decreases and buffer size increases. Decreasing in arrival rate means getting lower traffic load and increasing the buffer size means getting lower probability for the arriving packets to be dropped. Also it can be seen for a fixed service rate and arrival rate (i.e. traffic load), loss probability decreases as mean frame length and buffer size increase. Increasing the mean frame length means getting lower probability for a head-of-frame packet to arrive.

Figure 9 shows the loss probability versus buffer capacity without considering any discarding policy. It can be noticed for a fixed service rate that the loss probability decreases as arrival rate decreases. Decreasing arrival rate for a fixed service rate means getting lower traffic condition (load). Figure 10 shows the loss probability versus buffer capacity for both PMD and no control discarding policies. It can be noticed for a fixed service rate and arrival rate (same load) that the loss probability decreases as buffer size increases. It is also interesting to see that the loss probability in PMD is lower than in NO CONTROL.

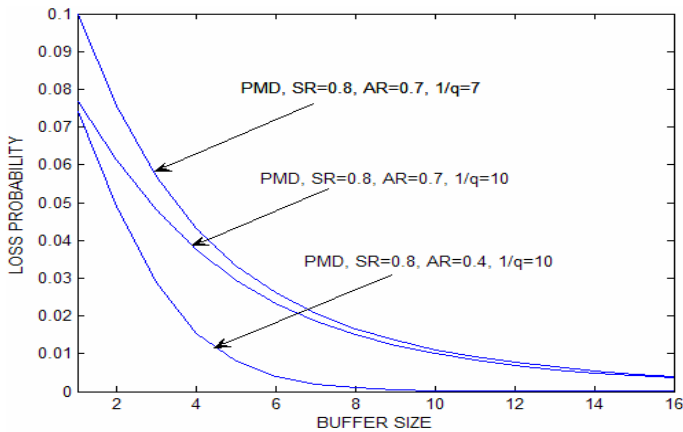


Figure 8: Loss probability versus buffer size (service rate (SR) = 0.8; arrival rates (AR) = 0.4, 0.7; 1/q = 7, 10)

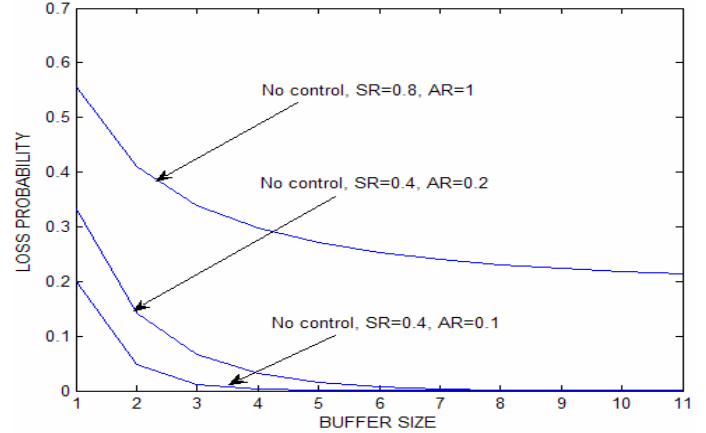


Figure 9: Loss probability versus buffer size (service rates (SR) = 0.4, 0.8; arrival rates (AR) = 0.1, 0.2, 1)

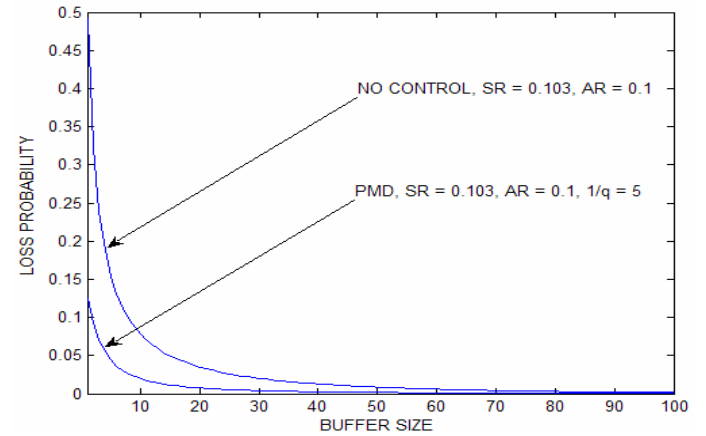


Figure 10: Loss probability versus buffer size (service rate (SR) = 0.103; arrival rates (AR) = 0.1; 1/q = 5)

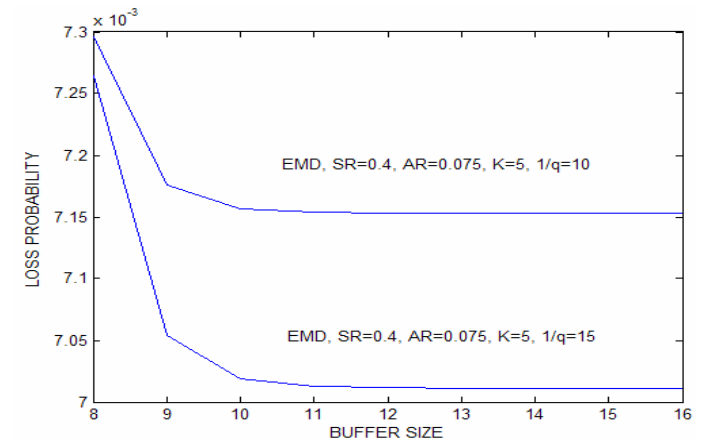


Figure 11: Loss probability versus buffer size (SR = 0.4; K=5; AR = 0.075; 1/q = 10, 15)

Figure 11 illustrates the loss probability versus buffer capacity for the EMD policy. It can be shown from Figure 11 that for a fixed traffic load, and threshold buffer occupancy level that the loss probability decreases as mean frame length increases. One important thing that can be noticed is that the loss probability

gets constants after a certain buffer size and this is not the case of PMD, the reason for that is K (threshold buffer occupancy level), so even though the buffer size gets larger and larger but we have fixed value of K. On the other hand the value of K can not be chosen randomly, so when the value of the threshold is chosen to be too low, the buffer is not well utilized since many frames which may have been accepted are discarded. Thus, high loss probability is obtained. Therefore, low QoS is achieved. Similarly, when the value of the threshold is chosen to be too high, the system acts almost like PMD policy and loses its main and relative advantage. However, the best value of K that achieves the best QoS is that value that maximizes the goodput.

Goodput is defined as the ratio of packets that belong to uncorrupted message (frame) to the total arriving packets at the network element's input [5]. The goodput G is expressed as [5]

$$G = \frac{\sum_{n=1}^{\infty} nP(D = n, B = 1)}{\sum_{n=1}^{\infty} nP(D = n)} \quad (68)$$

where D and B are random variables that represent the number of packets of a frame and the successful display of a frame (or message). B=1 represents success and B=0 represents failure.

From (68), the following expression is derived [5]:

$$G = q \sum_{n=1}^{\infty} n q (1-q)^{n-1} \cdot \sum_{i=0}^N P(B=1 | D=n, Q=i) P(Q=i) \quad (69)$$

where Q is the random number that represents the buffer occupancy at the arrival of a head-of-frame packet. For final numerical results for (69) see [5], for final explicit expression for (69) see [8].

VI. CONCLUSION

In this paper, we study and analyze the memoryless M/M/1/N model that supports both discarding policies (PMD and EMD) on MPEG video data transmission to avoid or reduce congestion. In this continuous-time Markov model the packets arrival follows Poisson distribution. The service times of packets are exponentially distributed (i.e. generated by a Poisson process). We have just one server with finite buffer size (N). The frame size (in terms of packets) is considered to be geometrically distributed with parameter q (i.e. the mean size of a frame as $1/q$ packets) and is taken based on the MPEG encoding pattern (e.g., IBBPBBPBBPBBPBB pattern, one of the most common patterns that are used in MPEG encoding). It is so interesting to see the effect of some important performance matrices like average buffer size, loss probability due to limited buffer size on that model with and without using these discarding policies. We have provided closed form expressions for these performance metrics, the average buffer occupancy, and loss probability. The results for these performance metrics are presented and explained under

different traffic conditions and frame lengths (in terms of packets).

VII. REFERENCES

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