다중 MPEG 비디오 전송을 위한 I-픽쳐 정렬 방안

박상현*

A Novel I-picture Arrangement Method for Multiple MPEG Video Transmission

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이 논문은 지방대학 혁신역량 강화사업의 연구결과로 수행되었음.

요 약

VBR (variable bit rate) MPEG 비디오 트래픽은 GOP(group of pictures)의 시작인 I-픽쳐에서는 다른 픽쳐들보다 매우 큰 양의 트래픽이 발생하기 때문에 GOP 구조에 따라 주기적 형태의 트래픽 발생 패턴을 가진다. 따라서, VBR MPEG 비디오 정보원이 다중화 될 때 I-픽쳐들의 시작 시간 배열은 다중화기의 셀 손실 특성에 큰 영향을 준다. 본 논문에서는 VBR MPEG 비디오 정보원들이 하나의 전송로로 전송되기 위해 다중화 될 때 다중화기에서의 셀 손실률을 최소화하기 위해서 각 비디오 정보원의 I-픽쳐 시작시간들을 배열하는 방안을 제시한다. 제안하는 방안에서는 정확한 I-픽쳐 시작 시간을 효과적으로 찾기 위해 다중화된 정보원의 셀 도착률이 전송로의 용량을 초과하는 확률을 이용하였다. 모의 실험을 통해 제안하는 방법이 기존의 방법들 보다 최적으로 비디오 정보원들을 다중화시키는 것을 보였다.

ABSTRACT

The arrangement of I-picture starting times of multiplexed variable bit rate (VBR) MPEG videos may significantly affect the cell loss ratio (CLR) characteristics of the multiplexed traffic. This paper presents an efficient I-picture arrangement method which can minimize the CLR of the multiplexed traffic when multiple VBR MPEG videos are multiplexed onto a single constant bit rate link. In the proposed method, we use the probability that the arrival rate exceeds the link capacity as the measure for the CLR of the multiplexed traffic. Simulation results show that the proposed method can find more optimal arrangement than existing methods in respect of the CLR.

키워드

video traffic modeling, statistical multiplexing, video traffic management, video traffic analysis

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접수일자 2004. 2. 16.

Ⅰ. Introduction

When multimedia consisting of voice, video, and data is transmitted over a network, video traffic consumes most of the bandwidth, and also requires a high level of quality of service (QoS) guarantee from the network. In order to reduce the bandwidth requirement and maintain the constant video qualities, therefore, VBR video compression is used. VBR video compression and transmission over networks offer good link utilization with statistical multiplexing which is a mechanism for reducing the bandwidth requirement of bursty and VBR traffic sources [1,2].

MPEG has been the most popular video compression scheme for providing multimedia applications. The MPEG video traffic is comprised of three picture types (I-, P-, and B-pictures) which generate different periodic traffic patterns depending on the GOP (group of pictures) structure. Also, I-pictures generate significantly larger traffic than other pictures, and hence the pattern of MPEG video traffic periodically shows distinguishable peaks at the time of I-picture. Thus, when several MPEG videos are multiplexed, the arrangement of I-pictures may significantly affect the cell loss ratio (CLR) of the multiplexed traffic [3,4]. That is, even for the same number of MPEG videos connected to a link, the CLR characteristics may become different according to the arrangement of I-picture starting times of individual sources, which is called the periodic peak position effect [4]. The periodic peak position effect may be reduced to some degree by using standard traffic control schemes. One of the most promising ways used in much of the previous works is traffic smoothing (or traffic shaping) [5,6]. Basically, traffic smoothing techniques aim at reducing the variability of the traffic on a source-by-source basis. Thus, unless the I-picture starting times of individual sources are directly controlled, the periodic peak position effect still remains. An I-picture arrangement method is a scheme that can manipulate the I-picture starting time of each source and then reduce the CLR of the multiplexed traffic.

In this paper, we propose an efficient I-picture arrangement method that can minimize the CLR of the multiplexed traffic for the multiple MPEG video transmission system. In the proposed method, we use the probability that the arrival rate exceeds the link capacity as the measure for the CLR of the multiplexed traffic.

This paper is organized as follows. In Section Ⅱ, the VBR MPEG video source model used in this paper is described. In Section Ⅲ, we propose an efficient I-picture arrangement method which is derived from the intensive investigations on the relationship between starting time arrangement and the CLR. In Section Ⅳ, we illustrate the experimental results of the proposed and existing methods. Finally, the conclusion remarks are presented in Section Ⅴ.

Ⅱ. Traffic model for multiplexed MPEG videos

In this section, we first propose a traffic model for a single VBR MPEG video source. Then, the traffic model for the multiplexed VBR MPEG videos is proposed by using the individual source models.

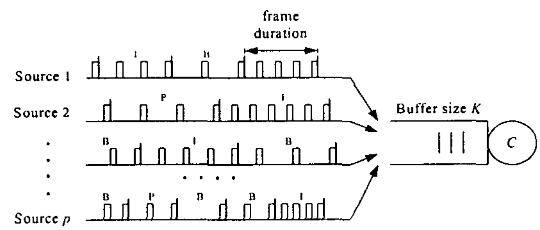


Figure 1. Multiple MPEG video transmission system with p sources and link capacity C.

Fig. 1 illustrates the multiplexer system under consideration where p video sources are served by an ATM multiplexer with output link capacity C. We assume that the video source uniformly transmits cells generated for one picture over one picture period.

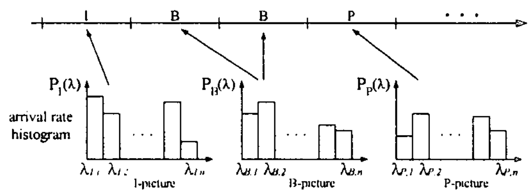


Figure 2. Single MPEG source model.

In the VBR MPEG video, each picture type (I-, P-,and B-pictures) appears periodically according to the GOP structure. The GOP structure is specified by two parameters (N, M), where N is the distance between two successive I-pictures and M is the distance between I- and subsequent P-pictures or two successive P-pictures. Because of this perio dic pattern, the VBR MPEG video traffic has complicated statistical characteristics in its whole sequence. However, the statistical char acteristics of a subsequence with only the same picture type are similar to those of non-MPEG-type VBR video traffic[3].
Therefore, the subsequence with the same picture type can be modeled in the traditional manner for non-MPEG-type video traffic. To model the subsequence of each picture type, we use the arrival rate histogram model [7], where the arrival rate is the number of cells generated for one picture divided by the picture period which is a reciprocal of the picture rate. Since the VBR MPEG video is a sequence of three picture types, it is modeled by a sequence of arrival rate histograms of three picture types according to its GOP structure. Fig. 2 shows a single source model which is a sequence with the three arrival rate histograms, where λ_k is the arrival rate of the kth histogram bin of the I-, P-, or B-picture type.

The traffic model of the multiplexed VBR MPEG videos is obtained from the individual MPEG video source models as follows: Fig. 3 shows an example where heterogeneous p VBR MPEG video sources are multiplexed. It is obvious that the multiplexed traffic of the periodic sources is also periodic. The period of $L = LCM(L_1, L_2, \ldots, L_p)$ the multiplexed traffic is , where represents the least common multip le and $LCM L_k$ de notes the period of the GOP of the kth source. The number of histograms of the mul tiplexed traffic depends on the arrangement of the I-pictures and the GOP structures of indi vidual sources. Let $t_{k,m}$ be the starting time of the mth picture of the kth source.

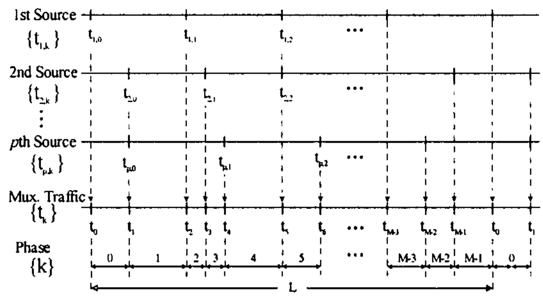


Figure3. Multiplexed traffic with heterogeneous p MPEG video sources.

The nth phase is defined as the nth interval when the $t_{k,m}$'s are arranged in time within L. If the number of phases is M, the multiplexed traffic can be modeled by M different arrival rate histograms. Let the random variables $X_{k,m}$ and X_n represent the arrival rate of the kth source for $[t_{k,m}, t_{k,m+1})$ and the arrival rate of the multiplexed traffic for $[t_n, t_{n+1})$, respectively, where t_n is the starting time of the nth phase. Since the arrival rate of the multiplexed traffic is the sum of the arrival rates of individual sources, X_n is given by

$$X_n = \sum_{\{(k,m) | t_{k,m} \le t_n, t_{k,m+1} \ge t_{n+1}\}} X_{k,m} \qquad (1)$$

Therefore, the histogram of X_n can be dire ctly calculated by convolving the histograms of $X_{k,m}$'s.

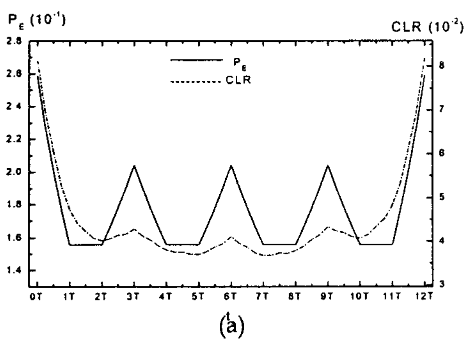
III. I-picture arrangement method

In this section, we present a new I-picture arrangement method where the probability that the arrival rate exceeds the link capacity, P_L, is used as the measure for the CLR. Using the traffic model presented in the previous section, we can determine P_L as follows:

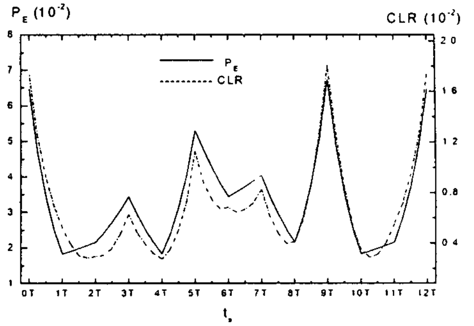
$$P_L = \frac{\sum_{n=0}^{M-1}(t_{n+1}-t_n)\sum_{i=1}^{B}(\lambda_{n,i}-C)^{+}P(X_n=\lambda_{n,i})}{\sum_{n=0}^{M-1}(t_{n+1}-t_n)\sum_{i=1}^{B}\lambda_{n,i}P(X_n=\lambda_{n,i})} \quad (2)$$

where $\lambda_{n,i}$ and B, respectively, are the arrival rate of the ith histogram bin and the number of histogram bins of X_n, and $s^{+}=max\{0,s\}$.

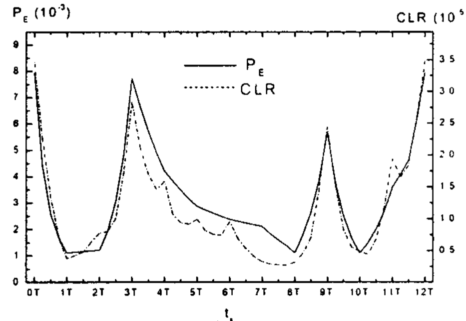
To investigate the relationship between P_L and the CLR, we obtain the CLR through computer simulation using some MPEG video sequences [8] as follows: In this simulation, the traffic intensity (ρ) is set to 0.6, buffer size (K) is 100 cells, and the number of multiplexed sources (p) is varied. I-picture starting times of individual sources are arranged in the following way. When p MPEG videos are multiplexed, the I-picture starting times of (p-1) sources called the existing sources are randomly distributed within the range $[0, L)$. The I-picture starting time of the pth source called the incoming source is varied within the range $[0, L)$.



(a)



(b)



(c)

Figure 4. CLR versus P_L curves : (a) p=2, (b) p=5, and (c) p=8.

Fig. 4 illustrates P_L determined using (2) and computer simulation results of CLR where t_s represents the I-picture starting time of the incoming source and T is the reciprocal of the picture rate. In Fig. 4, it is seen that the CLR curves are similar to the P_L curves and that the smallest CLR appears at t_s with the smallest P_L. Also, note that the CLR tends to decrease as t_s is far from t_s with the largest P_L. Therefore, in the proposed method, we select the I-picture starting time of the incoming source at t_s with the smallest P_L. If the smallest P_L appears at more than one position, we select the farthest one from t_s with the largest P_L among t_s's with the smallest P_L. Thus, the proposed algorithm can be formulated as follows: Let t_{min} and t_{max}, respectively, be the sets of t_s's with the smallest P_L and the largest P_L, and t_i^{min} and t_i^{max}, respectively, be the ith elements of T_{min} and T_{max}. Also, we define the distance between two points t_1 and t_2 as

$$d(t_1, t_2) = min\{(t_1 - t_2), (t_2 + L - t_1)\} \quad (3)$$

where $t_1 \geq t_2$. Then, we select the smallest one among the distances between t_i^{min} and elements in $T_{max} = \{t_j^{max} | j = 1, \ldots, N_{max}\}$ which is given by

$$d_i = \min_{1 \leq j \leq N_{max}} d(t_i^{min}, t_j^{max}) \quad (4)$$

where N_{max} is the number of elements in T_{max} Among the elements in $T_{min} = \{t_i^{min} | i = 1, \ldots, N_{min}\}$, the I-picture starting time t_s of the incoming source is determined by $t_s = t_k^{min}$ where $d_k = max_{1 \leq i \leq N_{min}} d_i$. Here, N_{min} is the number of elements in T_{min}.

IV. Experimental results

For experiments, we use the MPEG coded video sequences obtained from [8]. Table 1 shows main statistics of the used sequences. The GOP parameters (N, M) of all the video sequences are (12,3) and the picture rates are 30 pictures/s. It is assumed that the payload of an ATM cell consists of 48 bytes of the data.

Table 1. Main statistics of sequences used in experiments

Sequence	Pictures		GOP's	
	Mean (cells)	Peak/ Mean	Mean (cells)	Peak/ Mean
Starwars	24.74	13.18	296.88	3.96
Dino	34.55	9.03	414.56	3.96
Asterix	58.69	6.54	704.25	4.00
Atp	57.49	8.66	689.91	2.98

For the analysis of the proposed I-picture arrangement method, each MPEG video source is modeled by the three arrival rate histograms for I-, P-, and B-pictures. In the arrival rate histogram model, the number of bins of the arrival rate histogram affects the performance accuracy as well as the computational complexity. Through extensive simulations, we have found that eight bins are sufficient in modeling each picture type of MPEG video. Further increasing the number of bins does not result in a significant change in the I-picture arrangement. For the multiplexed traffic, we have also found that 20 bins are sufficient to model each phase. Fig. 5 shows the CLR as a function of the number of sources when traffic intensity is 0.8 and buffer size is 100 cells. Three I-picture arrangement methods are compared: (i) the random arrangement method where the I-picture starting times are randomly distributed over the range [0, L); (ii) the Krunz method [3] which can minimize the peak cell rate of the multiplexed traffic; (iii) the proposed method. From Fig. 5, we observe that when the traffic intensity is constant, the CLR decreases as the number of multiplexed sources increases. That is, the more the number of multiplexed sources, the better the CLR performance. Also, it is seen that the proposed method produces the least CLR among the three different arrangement methods regardless of the number of multiplexed sources.

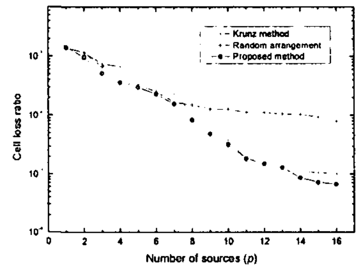


Figure 5. CLR characteristics as a function of the number of sources for K=100 and ρ=0.8.

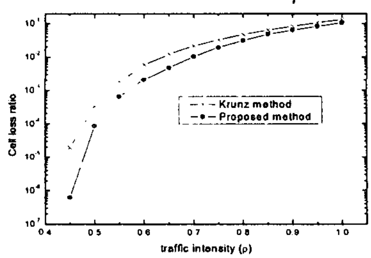


Figure 6. CLR characteristics as a function of traffic intensity for K=100 and p=5.

Fig. 6 shows the results on CLR for the traffic intensity when the number of sources is 5 and the buffer size is 100 cells. It is shown that the proposed method outperforms the Krunz method all regions. Also, note that as the traffic intensity decreases, the difference between the proposed method and the Krunz method increases.

V. Conclusions

The arrangement of I-picture starting times of multiplexed VBR MPEG videos may significantly affect the CLR characteristics of the multiplexed traffic. In this paper, we investigated the effects of the I-picture starting time arrangement of the multiplexed VBR MPEG videos to the CLR performances. We then proposed a starting time arrangement method for an incoming source that can minimi ze the CLR of the multiplexed traffic including the incoming source itself without adjusting the starting times of existing VBR MPEG videos. The proposed method can be applied to multiplexing MPEG video sources regardless of the GOP structures and the picture rates of individual sources, while the existing method like the Krunz method can be applied to only homogeneous sources. Experimental results show that the proposed method can find more optimal arrangement than existing methods in respect of the CLR. The proposed I-picture arrangement method can be effectively used for the multiple MPEG video transmission system such as video-on-demand (VOD) and mobile multimedia systems where it is possible to know the arrangement of the actual starting times of existing sources and arrange the starting time of the incoming source.

References

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