INTERNATIONAL JOURNAL OF SATELLITE COMMUNICATIONS AND NETWORKING
Int. J. Satell. Commun. Network. 2004; **22**:217–229 (DOI: 10.1002/sat.781)

Integrating the scene length characteristics of MPEG video bitstreams into a direct broadcast satellite network with return channel system

Fatih Alagöz*,†

Department of Electrical and Electronics Engineering, Harran University, Sanliurfa, Turkey

SUMMARY

In order to optimize the network resources, we should incorporate all the available information into the network design. However, incorporating irrelevant information may increase the design complexity and/or decrease the performance of the network. In this paper, we investigate the relevance of integrating the scene length characteristics of moving pictures expert group (MPEG) coded video bitstreams into a direct broadcast satellite (DBS) network with return channel system (DVB-RCS). Due to the complexity of the studied system, unless disputable simplifications are made, it is hard to achieve a mathematical foundation for this integration. Our analysis relies on extensive set of simulations. Firstly, we achieve the scene length distributions for MPEG bitstreams based on the proposed scene change models and their subjective observations of the actual video. We show that these models may be used to estimate the scene length of MPEG bitstreams. We then integrate this estimation into a DBS network simulator. Finally, we show that the scene length characteristics may be used to improve the DBS network performance under certain conditions. Copyright © 2004 John Wiley & Sons, Ltd.

KEY WORDS: scene change model; MPEG video bitstreams; DBS networks

1. INTRODUCTION

Recently, numerous researches have been focused on the scene length distributions to help us understand the behaviour of moving pictures expert group (MPEG) coded variable-bit-rate (VBR) video bitstreams. The scene length characteristics may be used to utilize the network resources, alleviate buffer overload, and design better codecs, etc. [1–13]. Unfortunately, there is no largely accepted mathematical model that represents the scene length characteristics of the MPEG video bitstreams. Some heuristics and measurements are available in References [2, 3, 4, 8, 13, 23]. For example, Krunz and Ramasamy established a relationship between the scene length statistics and the short-range/long-range dependence (SRD/LRD) of their model [8]. They show that when the intra-scene dynamics exhibit SRD, the model exhibits LRD if and only if the second moment of the scene length is infinite. The impact of traffic correlations on the

*Correspondence to: Fatih Alagöz, Department of Electrical and Electronics Engineering, Harran University, Sanliurfa, Turkey.
† E-mail: alagoz@harran.edu.tr

Contract/grant sponsor: DARPA Global Mobile Information Systems Program; contract/grant number: DABT-95-C-0103

packet loss performance at a video buffer has been investigated for various distributions. For Pareto distributed scene lengths, it is observed that the performance is rather insensitive to changes in the buffer size even when the video model shows SRD behaviour [8].

Based on the bitstream observations, it is obvious that some spikes may occur due to periodic coding refresh in the ongoing scene. For example, due to the MPEG coding scheme, I frame may produce such spikes. Moreover, it is widely accepted that a spike may also occur due to renewal of the scene: a new scene of the last frame content from a different perspective, or a new scene with completely different content. These are the moments that may require higher number of bits (packets) to represent the current frame at the output of the encoder [4]. Therefore, during an MPEG video transmission in a link, an extreme spike resulting from a scene change may cause packet loss due to buffer overflow, and thus the designed network may suffer. If we estimate a possible scene change in n seconds we could take corrective actions to alleviate the buffer overload. This makes sense if we have a single video source in the network. The question we study in this paper is that whether or not to integrate the scene length characteristics of MPEG video bitstreams into direct broadcast satellites (DBS) networks carrying multiplexed (aggregated) video sources.

Figure 1 depicts the time phased control concept for the considered DBS system. The description of the DBS system is given in Reference [14]. The operational concept of the DBS system is as follows. During the transmission of aggregated VBR traffic, the transmit (T_x) queue at the uplink router may build up. In this case, T_x queue manager may apply basic rules to alleviate buffer overload. For example, I frame maybe given priority over P and B frames due to the error resilience characteristic of the MPEG coding scheme [15]. However, this action may result in sharp degradation in the subjective video quality yet it may not prevent the overload since a highly active scene may last several seconds. Therefore, as part of short-term traffic variation control, the source controller (MPEG encoder) may need to reduce the frame sizes accordingly so that the degradation in the video quality is smoother as compared to that for frame dropping [15].

On the other hand, in order to utilize the return link capacity, the end receiver's QoS feedback is, in general, less frequently reported depending on the system architecture [14, 16–18]. Recently, direct video broadcast-return channel system (DVB-RCS) has taken major attention from the research community [16]. Similarly, in the US Army GloMo Project [14], the considered DBS system uses low-bandwidth low earth orbit (LEO) Satellites for the return link messages. Therefore, before we receive the end-receiver's QoS feedback at a longer time scale,

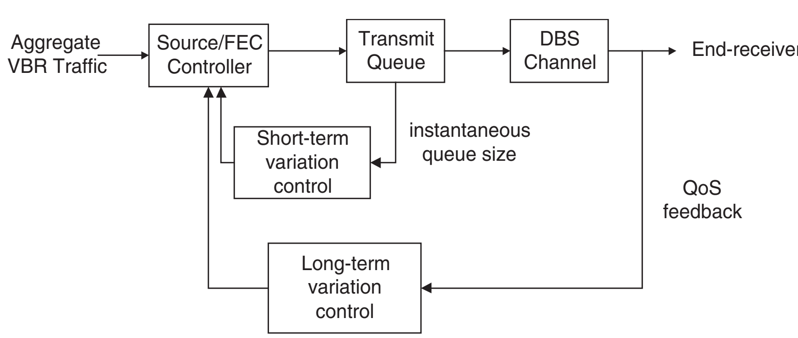

Figure 1. Time phased control concept in the considered DBS-RCS system.

we may prevent possible congestion based on the queue buildup information. Let, T_Q and T_R denote the transmit queue monitoring time scale and the return link QoS report interarrival time, respectively. In order to prevent the temporal congestion in the queue, in the equation $T_R = kT_Q$, we should find k over which to estimate the excessive rate, $\Delta\omega$, which is measured as the difference between the sum of the instantaneous rates and the DBS link capacity. The parameter k should be selected in such a way that it should not cause for overreaction to instant changes in the traffic mixture. In order to find an appropriate k value we utilize the scene length characteristics of MPEG bitstreams. We consider the scene length effect of the multiplexed bitstreams as the expected time for the next busy period during which the aggregate traffic may exceed the link capacity by some large amount.

In general, the scene length characteristics may be used as follows:

- *In codec design*: In order to estimate the next quantization time at the source encoder buffer, one may use the scene length distribution [1].
- *In VBR source modelling*: The critical points during our observations may be scaled into a number of classes representing the activity levels in the ongoing scene. Then, one may develop VBR models using Markov states reflecting the level of activity and autoregressive process reflecting the particular activity in that state [1, 8].
- *In queue management*: The scene lengths may be used to estimate the duration of the busy periods. One may use this information for controlling the queue by sending feed back to the source encoder [2].

There may be other use of scene length characteristics yet this paper focuses on the queue management use by estimating the time scale to take corrective actions. We show that the scene length characteristics may be included in the DBS networks carrying MPEG video bitstreams. The rest of the paper is organized as follows. In Section 2, we propose two new approaches for modelling the scene change of the MPEG video bitstreams. Section 3 presents the scene length analysis for single and multiplexed video bitstreams. Section 4 presents the relevance of integrating the scene length characteristics into the DBS networks. In Section 5, we conclude our work.

2. SCENE CHANGE MODELS

The number of bits required for a new frame at the output of MPEG encoders depends on several aspects;

(i) *Codec and coding scheme*: the periodicity of intrafield (I) frames. For example, an MPEG-1 codec works with I frame refreshment rate of 12 while it is 15 for an MPEG-2 codec. Commercial MPEG codecs, which are designed with various parameters, may produce different bitrates for the same video source.

(ii) *Continuity of the motion within a scene*: depending on the motion activity, some portion of the frame may be changed due to abrupt camera zooming, panning, etc. There is some correlation among the information contents of successive frames and

(iii) *Cutting into a new scene*: depending on the new frame, most of the frame may be replaced with a completely new scene. There is no (or very small) correlation among the information contents of successive frames.

We define the scene change as *cutting into a new scene*. It is reported in Reference [3] that by observing the actual movie frames and corresponding bit rate sequences in lockstep, it was possible to ascertain that the scene changes do indeed coincided with abrupt sustained changes in bit rate magnitude. For DPCM coding scheme, in Reference [4], Heyman defined the scene change condition as follows:

$$(X_{i+1} - X_i) - (X_i - X_{i-1}) > lnum \quad (1)$$

where X_i denotes the number of bits in the ith frame. At a scene change, the second-order difference of X_i should be a large negative real number, and *lnum* is defined as the second-order difference divided by the average of past few frames.

Since the MPEG coding scheme is different than the DPCM coding scheme, it is not possible to use the above strategy on a frame basis. Specifically, the MPEG coding scheme consists of different type of frames having unequal bitrates; intra-picture (I), predictional-picture (P) and bi-directional picture (B). We adapt the above strategy on group of pictures (GOP) basis. A GOP in the MPEG coding scheme is periodic and represented by $G(m,n)$, where m is number of P-pictures and n is number of consecutive B-pictures. For the MPEG coded *Starwars* movie [19], $m = 3$, and $n = 2$, thus a GOP has the following pattern: IBBPBBPBBPBB with a GOP duration of $\frac{1}{2}$ s.

The scene lengths in actual movies are determined by the technical and artistic personnel; generally, a scene length should last more than one GOP so that it is not perceptually annoying, yet there may be GOP intervals including more than one scene changes. Unfortunately, the scene change models that we propose below cannot capture these instances. In addition, there are overlapped scenes taken by a number of cameras. One may need to examine such scenes by observing the actual movie frames and corresponding bit rate sequences in lockstep. As the empirical bitstreams under investigation have a few of such scenes, the proposed models will not consider these moments as scene change.

2.1. Model A: scene change model based on first-order difference in GOP

Let G_i denote the total number of bits in the ith GOP. We declare a scene change, if the first-order difference satisfies the following equation:

$$(G_i - G_{i-1}) > lnumA \quad (2)$$

where *lnumA* is a large number which is defined as the first-order difference in GOP sizes divided by the average of past few GOPs. This strategy for declaring a scene change is similar to the ones given in References [5, 6], except the fact that they declare a scene change based on the first-order difference in I frames. A shortcoming of I frame based declaration method may be explained as follows. Assume that there is a scene change in one of the B frames in a GOP, and the two consecutive I frames are equal in magnitude but the corresponding scenes may be completely different. This scene change will be missed using the I frame based scene change model. Since that particular B frame is included in GOP calculation, the corresponding GOP sizes will be sufficiently different, and thus the new GOP will be counted as a scene change in this model.

2.2. Model B: scene change model based on second-order difference in GOP

Being an extension of Model A, this model assumes a scene change, if the second-order difference satisfies the following equation:

$$(G_i - G_{i-1}) - (G_{i+1} - G_i) > lnumB \tag{3}$$

and *lnumB* is defined as the second-order difference divided by the average of past few GOPs.

The averaging over the past few GOPs is used to account for the ongoing scene characteristics. We found that averaging over six or more GOPs performed the same.

3. SCENE LENGTH ANALYSIS

In order to test the *lnumA* and *lnumB* criteria, we gathered scene change statistics in the visual sense for 1 68 904 frames long *Starwars* movie. Figure 2 depicts the corresponding scene length density function, which was achieved based on subjective observation. The average scene length and the standard deviation were 3.3259 and 4.3451 s, respectively. Only 4% of the time the scene length was greater than 10 s. Figure 3 shows the *lnumA* and *lnumB* histograms for the best critical points (Cr.GOP.A = 0.181 and Cr.GOP.B = 0.284) so that the empirical bitstream and observed actual movie have the same average scene lengths.

Figure 4 portrays a short clip from *Starwars*, and the scene change counts in response to the GOP bitrate variations. For example, in the visual sense, the first 30 s (60 GOP duration) shows the scene in which a 'starship' appears and slowly vanishes in the space. Both of the models do not count any scene change as shown in middle and bottom parts of the figure. We can observe that the first two scene changes for Model A (MA count) was not counted as scene changes for Model B (MB count). The magnitude of the *y*-axis of the specific scene change reflects the

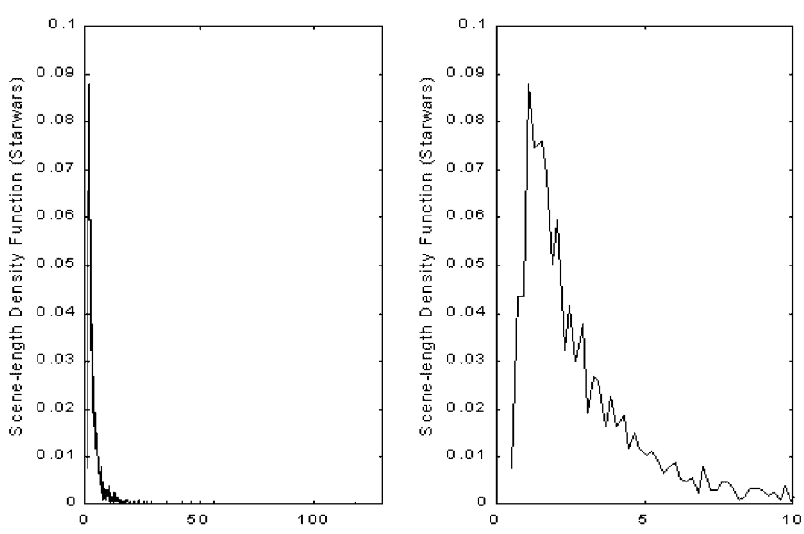

Figure 2. Scene length density function of *Starwars* movie.

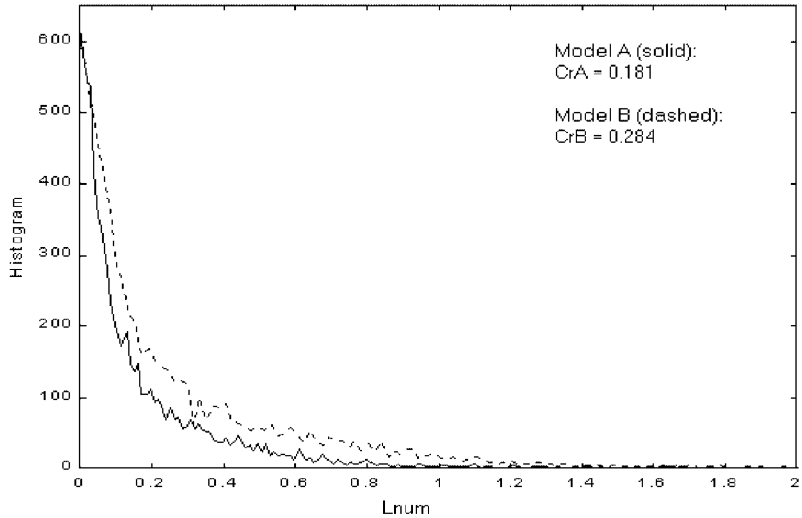

Figure 3. Histogram of test criteria.

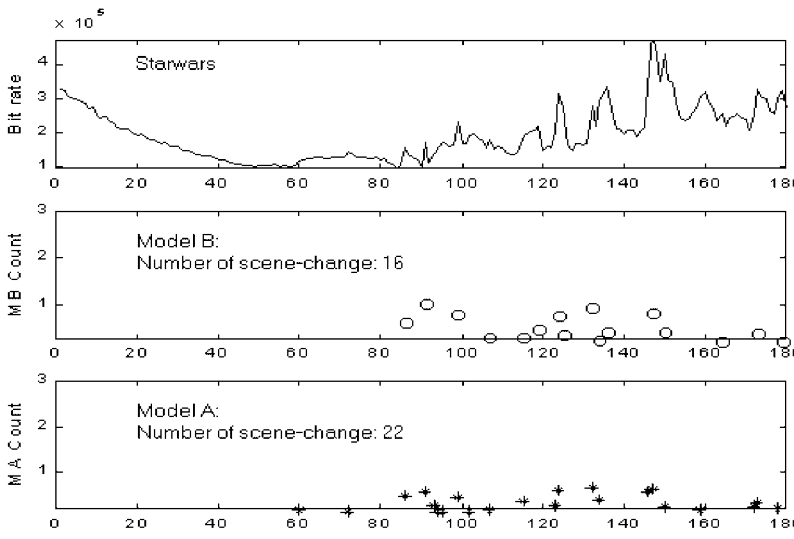

Figure 4. Comparison of real and generic scene change counts.

difference between two successive GOP bit rates. For example, a scene change from 'space' to 'two-warriors fighting' would yield a high value as expected.

Table I presents the basic statistics of the bitstreams under investigation. All the bitstreams are coded with G(3,2) of 12 frames/GOP. To fit the scene length distributions for these bitstreams, Gamma, Weibull, lognormal, and Pareto distributions are used as candidate distribution functions [20]. Fitness technique, which is described in Reference [21], is based on the comparison of the standardized third moment ($\gamma_3 = \mu_3/\sigma^3$) versus the coefficient of variation

Table I. Basic statistics of MPEG coded VBR bitstreams.

Bitstream Name	Length (frame)	Peak GOP (kbits)	Mean GOP (kbits)	Std. GOP (kbits)	Peak/mean (GOP)
Starwars	1 68 904	945.15	187.95	73.542	5.03
Mtv	40 000	1280.79	295.32	137.57	4.33
Terminator	40 000	407.51	130.85	45.182	3.11
Silence of Lambs	40 000	462.06	877.30	53.002	5.26
Goldfinger	40 000	956.37	291.67	109.17	3.28
Soccer (sports)	40 000	1281.22	325.57	123.80	3.94
Asterix (cartoon)	40 000	1079.43	268.22	124.85	4.02
News	31 000	949.54	247.96	108.98	3.83
Mr.Bean	40 000	863.27	211.57	105.72	4.08
Talk show	40 000	470.64	174.47	56.526	2.70

Table II. Scene length statistics using Models A and B.

Name	Model A mean (s)	Model B mean (s)	Model A $\gamma_1 = \sigma/\mu$	Model B $\gamma_1 = \sigma/\mu$	Model A μ_3	Model B μ_3
Starwars	3.3287	3.3271	3.6230	3.8121	6.7377	9.9022
Mtv	2.5099	2.5252	2.5178	2.5517	3.8429	4.5822
Terminator	2.5444	2.5920	2.2351	2.0810	2.2034	2.5625
Lambs	4.0725	4.1853	4.2351	3.9228	2.1256	2.3579
Goldfinger	6.3654	5.9783	6.5394	7.8713	2.4092	3.1585
Soccer	5.7370	6.6260	5.8336	7.2904	1.6188	3.6415
Asterix	2.9855	3.0431	2.9227	2.6944	2.3332	2.7454
News	8.1529	8.9476	11.8735	13.4587	3.9808	4.6152
Mr.Bean	7.7934	9.2207	11.3756	13.2511	3.0867	3.5480
Talkshow	6.8223	6.5098	7.6860	7.3263	3.0673	2.8163

($\gamma_1 = \sigma/\mu$) where μ, σ and μ_3 denote the mean, standard deviation and third central moment, respectively.

Table II presents the additional statistics for the test bitstreams. Models A and B performed closely in representing the average scene length except for *Mr.Bean* and *News* (low activity motions). For *Starwars*, the third centralized moments for Models A and B were relatively different due to the large sampling errors of the third centralized moments. In the DBS simulator we used the *Starwars* movie for it is a well known and tested bitstream. Although the simulator performs its operations based only on the average scene length, one may improve the system performance by including the higher order statistics of the scene length distribution.

3.1. *On the effect of scene change models on multiplexed bitstreams*

In order to investigate the scene length effect on the multiplexed video bitstreams, we use the same *lnumA* and *lnumB* criteria defined earlier for Models A and B, respectively. We henceforth call the multiplexing effect on the average scene length as the estimated time scale (T_Q). Because, an appropriate k in the equation, $T_R = kT_Q$, should provide better performance results in the

DBS network, and thus, T_Q will reflect the expected time for the next busy period during which the aggregate traffic may exceed the link capacity by some large amount [14].

3.1.1. Homogeneous video sources. Unfortunately, there is almost no chance to find two or more actual VBR bitstreams that exhibit the similar statistical characteristics including bitrate as well as scene length statistics. We gather such bitstreams by using the circular-multiplexing technique, i.e. arrange the bitstreams as a circular list, start each bitstream randomly (or shifted by s units), and then proceed sequentially until the circle is completed. In this paper, the multiplexing is done on GOP basis by shifting the original bitstream for $s = 500$ s using the circularly shifted multiplexing technique.

Figure 5 shows the number of multiplexed bitstreams versus estimated time scale for *Starwars*. In addition to the results of the proposed models, Model A (GOP based) and Model B (GOP based), we include the results for Model A (I frame based) and Model B (I frame based) [5, 6]. The critical points for I frame based models are determined as Cr.I.A $= 0.07$ and Cr.I.B $= 0.132$, respectively. Since I frame based models may not include the scene changes within a GOP, they underestimate the time scale. Henceforth, we ignore I frame based models in the remaining part of the paper. Figure 5 suggests that as the number of the multiplexed bitstreams increase, the use of scene length information becomes ineffective. While Models A and B perform closer for smaller number of multiplexed bitstreams, the estimated time scale for Model A increases much faster than that for Model B when more than 15 bitstreams are multiplexed.

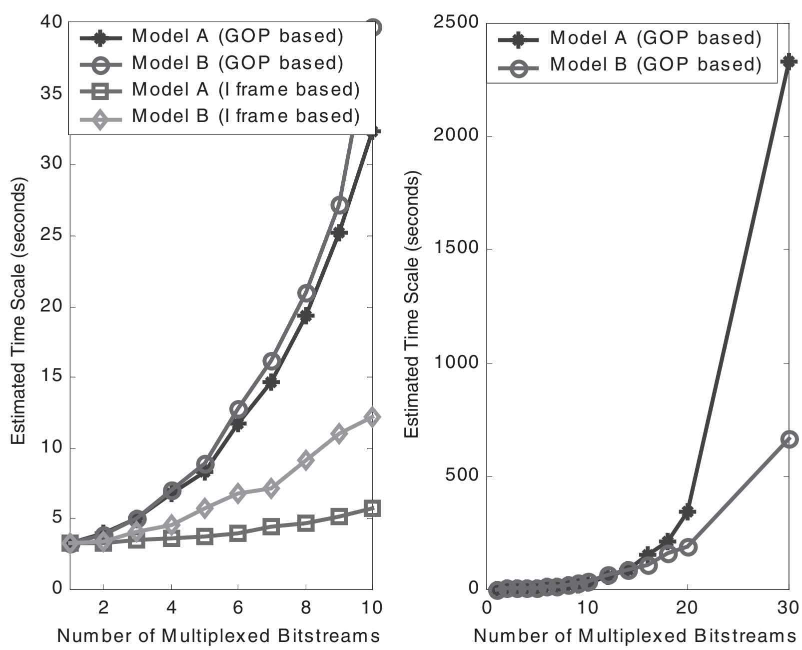

Figure 5. Number of multiplexed bitstreams (*Starwars*) versus estimated time scale using Models A and B.

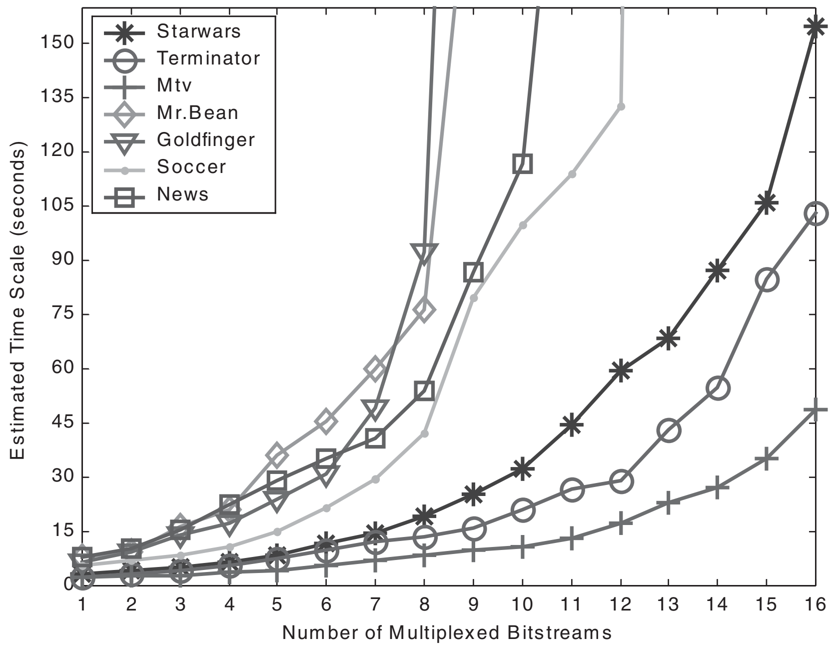

Figure 6. Number of multiplexed bitstreams versus estimated time scale using Model A.

3.1.2. Heterogeneous video sources. To explore the benefit of our algorithm for the multiple video sources with varying scene activity levels, we present Figures 6 and 7 for Models A and B, respectively. These figures suggest that there is more potential on multiplexing for high scene activity bitstreams as compared to that for low scene activity bitstreams. For practical purposes, these bitstreams may be divided into a few classes such as high activity (HA), medium activity (MA) and low activity (LA) motion based on their scene length statistics presented in Table II. The bitstreams belonging to different classes may be multiplexed to estimate the time scale in the actual DBS network. We consider *Mtv*, Goldfinger and *News* as examples of HA, MA and LA level video sources, respectively. These classes are multiplexed within each group and cross groups. As expected, for all the classes, the multiplexed bitstreams tend to have relatively higher average scene lengths both for Models A and B. For example, the average scene lengths for the multiplexing of 3 HA level bitstreams with Models A and B are 3.03 and 3.33 s, respectively. They were 15.4 and 23.5 s for 3 LA level bitstreams, and 14.0 and 20.5 s for 3 MA level bitstreams, respectively. As an example for a real-life scenario, we multiplexed nine bitstreams having different activity levels (3HA, 3MA, and 3LA). The resulting average scene lengths were 171.2 and 460 s for Models A and B, respectively. On the other hand, the average scene lengths for multiplexing 9 of HA level bitstreams, namely, *Mtv*, *Terminator*, and *Starwars* resulted in 10.7, 16.0 and 25.2 s for Model A, and 9.7, 22.9 and 27.2 s for Model B, respectively. However, the multiplexed video sources cannot be restricted with scene activity levels, and the real-life scenarios may include multiplexed bitstreams with various activity levels. Therefore, in a realistic scenario, multiplexing 10 or more of video bitstreams may result in an average scene length at the order of minutes. Figures 6 or 7 may be used to determine the estimated time scale (T_Q) for the desired DBS system parameters and quality of service.

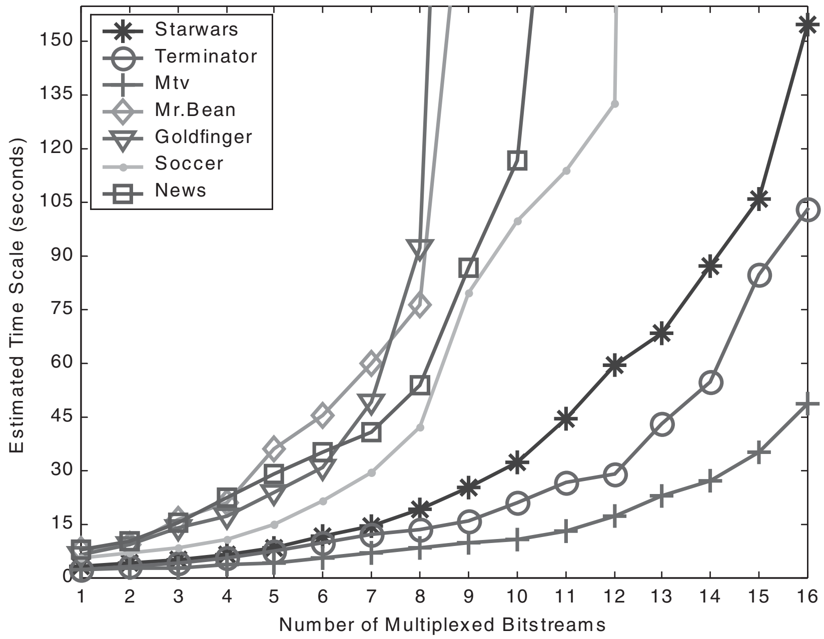

Figure 7. Number of multiplexed bitstreams versus estimated time scale using Model B.

4. RELEVANCE OF INTEGRATING SCENE LENGTH

In order to show the relevance of integrating the scene length characteristics into the DBS network design, we performed extensive set of simulations using the previously developed DBS network simulator presented in Reference [14]. These simulations include the changes in T_Q, T_R, and DBS link capacity. To simplify the analysis and have a better understanding of the performance results, we chose the same statistical characteristics for all VBR bitstreams while ABR services were not considered. *Starwars* movie VBR traffic (Table III) was generated following the model presented in Reference [22]. The DBS channel is assumed as based on a frame error rate of 10^{-4} using FEC rate of $\frac{3}{4}$ for forward link. We assume perfect return link.

Three sets of simulations were performed for the same channel conditions and VBR service requests, for total of 1200 s. The difference in the first set of simulations was only in the estimated time scale T_Q (2, 3, 5, 10, 15, and 30 s) for controlling the queue size. We assume that the QoS feedback report interarrival time scale, T_R, is set to 30 s. This is somewhat a reasonable number for the simulation purposes. According to the scene length analysis provided in Figure 5, we expect that the estimated time scale $T_Q = 15$ s should provide the best performance results for about (6–7) services in progress. For a DBS link capacity of 3 Mbps, a similar number of active services (6–7) can be achieved for average bitrate of 498 kbps (*Starwars* with $\frac{3}{4}$ FEC coding rate).

We calculated the performance metrics given in Reference [14]. The QoS measure was calculated as the rate loss seen by the end-receiver and is defined as

$$\text{QoS}_T = 1 - \frac{\Delta R_s + \Delta R_d + \Delta R_c}{R_n} \tag{4}$$

Table III. MPEG video traffic characteristics.

Traffic	MPEG coded VBR
Generated traffic: *Starwars*	GOP pattern: IBBPBBPBBPBB Frame duration = 1/24 s Mean = 187 kbits/GOP; Std = 72 kbits/GOP Max. source reduction rate = 47kbits/GOP
VBR service time	600 s
Request time epoch	600 s

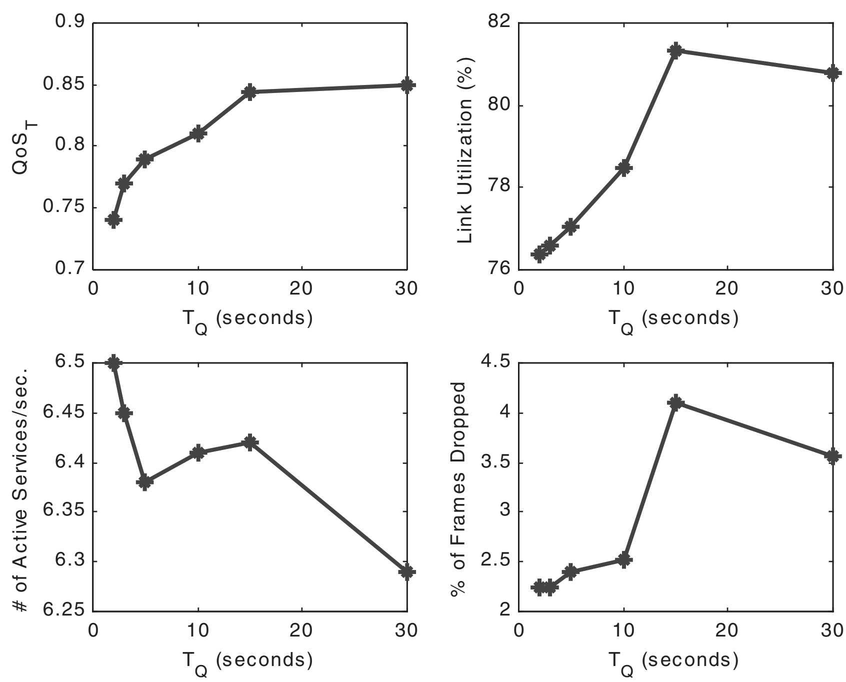

Figure 8. DBS simulation results for the estimated time scales.

where ΔR_s accounts for changes in MPEG source rate due to congestion, ΔR_d accounts for rate reduction due to dropped frames, ΔR_c accounts for sum of rates of all frames that are received with error or lost in the channel and R_n is the nominal rate. Note that ΔR_s, ΔR_d, and ΔR_c are parameters dependent on the traffic rate, channel state, and control actions.

Figure 8 depicts the DBS simulation results for the estimated time scales. One may consider that by including the scene length characteristics the complexity (overhead) was increased in the system. However, for $T_Q = 15$ s, i.e. $k = 2$, we achieved the best overall performance results. As suggested by the scene length analysis, i.e. the time scale is most effectively estimated at $T_Q = 15$ s, we achieved the highest link utilization, and slightly lower number of active (and completed) services over smaller T_Q time scales. The simulation results also confirmed that T_Q should be selected in such a way that it should not overreact to instantaneous changes in the traffic, i.e. avoid smaller T_Qs. It can be clearly seen that the smaller the T_Q time scale the smaller the fraction of dropped frames. For $T_Q = 15$, we achieved profoundly higher QoS_T measures over smaller T_Q, and nearly same QoS_T measure as in $T_Q = 30$ s. If the scene length characteristics were not integrated into the system, i.e. $T_R = T_Q = 30$, the highest QoS_T would be achieved at the expense of the lowest number of active (and completed) services. On the contrary, for smaller T_Q (2 and 3 s), the highest number of active (and completed) services were achieved at the expense of lowest average utilization and QoS_T.

In the second set of the simulations, as part of return link system architecture, we kept the same link capacity, and changed the QoS feedback report interarrival time, ($T_R = 60$, 90, 120, and 180 s). For each T_R value, we repeated the first set of simulation. As expected, since the number of active services was approximately the same, for $T_Q = 15$, the overall performance at all T_R values was superior to that for other estimated time scales. The corresponding performance measures were similar to the case with $T_R = 30$ s. This suggests that regardless of T_R time scale, we should estimate the excessive rate based on the T_Q value achieved by the scene length analysis.

The last set of simulations was intended for the investigation of the effect of scene dynamics for higher number of active services in the system. More services can be accommodated in two ways: increasing the capacity, or changing the parameter in statistical multiplexing gain. We increased the DBS link capacity ($C = 4$, 6, and 8 Mbps) to accommodate more (8–20) services. We observed that the estimated time scale, T_Q, achieves the highest utilization indicating higher average QoS_T and/or higher total number of completed services. However, when we had more than 15 active services in the system the effect of scene dynamics vanished. This was in agreement with the results given in Figure 5.

Similarly, Figure 6 or 7 suggest that if we were to use *Mtv* or *News*, the estimated time scales should have been set to 5 or 30 s, respectively, to achieve the highest performance results for about six active services in progress. Furthermore, depending on the DBS system parameters, T_Q for multiple video sources with varying scene activity levels may be utilized with respect to Figure 6 or 7.

5. CONCLUSION

We have investigated the relevance of integrating the scene length characteristics of MPEG coded video bitstreams into a DBS network with RCS. We first proposed two scene change models to characterize the scene length distributions. The scene length effect of the multiplexed bitstreams was considered as the expected time for the next busy period during which the aggregate traffic would exceed the DBS link capacity by some large amount. In order to investigate the relevance of integrating the scene length characteristics into the networks, the DBS network simulator developed earlier was used. Based on extensive simulations and analysis, we showed that one may incorporate the scene length characteristics into the network design when a few numbers of MPEG video sources are multiplexed on the same link, e.g. actual DBS networks carrying MPEG coded video bitstreams.

ACKNOWLEDGEMENTS

This work was performed as part of the DARPA Global Mobile Information Systems Program under contract number DABT-95-C-0103 to the U.S. Army of Intelligence Center Fort Huachuca, AZ. Author thanks anonymous reviewers for their very useful comments.

REFERENCES

1. Yegenoglu F, Jabbari B, Zhang Y. Motion-classified autoregressive modelling of variable bit rate video. *IEEE Transactions on Circuits and Video Technology* 1993; **3**(1):42–53.
2. Alagöz F. Scene length characteristics of MPEG coded video bitstreams. *Proceedings of the Sixth Symposium on Computer Networks, BAS2001*, Gazimagosa, Cyprus, June 2001; 80–89.
3. Melamed B, Pendarakis DE. Modeling full-length VBR video using Markov-renewal-modulated TES model. *IEEE Journal on Selected Areas in Communications* 1998; **16**(5):600–611.
4. Heyman DP, Laksman TV. Source models for VBR broadcast-video traffic. *IEEE/ACM Transactions on Networking* 1996; **4**(1):40–48.
5. Krunz M, Sass R, Hughes H. A study of VBR MPEG-coded video traffic and associated multiplexing performance. *Computer Systems Science and Engineering Journal* 1996; **11**(3):135–144.
6. Krunz M, Tripathi SK. Modeling bit rate variations in MPEG sources. *Internet Draft*, URL: www.cs.umd.edu/krunz, Institute for Advanced Computer Studies, University of Maryland at College Park, MD, May 1997.
7. Jelenkovic P, Lazar A, Semret N. The effect of subexponentiality in MPEG video streams on queueing behaviour. *IEEE Journal on Selected Areas in Communications* 1997; **15**(6):1052–1071.
8. Krunz M, Ramasamy A. Correlation structure for a class of scene-based video models and its impact on the dimensioning of video buffers. *IEEE Transactions on Multimedia* 2000; **2**(1):27–36.
9. Dawood A, Ghanbari M. Content based MPEG video traffic modelling. *IEEE Transactions on Multimedia* 2000; **1**(1):77–87.
10. Frater MR, Arnold JF, Tan P. A new statistical model for traffic generated by VBR coders for television on the broadband ISDN. *IEEE Transactions on Circuits and Systems for Video Technology* 1994; **4**(6):521–526.
11. Rose O. Simple and efficient models for variable bit rate MPEG video traffic. *Performance Evaluation* 1997; **30**:69–85.
12. Borsos T. A practical model for VBR video traffic with applications. *Proceedings of the MMNS*, Chicago, USA, 2001; 85–95.
13. Lakshman TV, Ortega A, Reibman A. Variable bit-rate video: tradeoffs and potentials. *Proceedings of the IEEE* 1998; **86**(5):952–973.
14. Alagöz F, Vojcic B, Pickholtz R, AlRustamani A. On the effects of traffic mixture in direct broadcast satellite networks. *International Journal on Satellite Communications* 2002; **20**(4):293–306.
15. Yeadon JN. Quality of service filtering for multimedia communications. *Ph.D. Dissertation*, Computing Department, Lancaster University, Lancaster, LA1 4YR, UK, May 1996.
16. Jamalipour A. Satellites in IP networks. *Wiley Encyclopedia of Telecommunications*, January 2003.
17. Thomas SA. *IPng and TCP/IP Protocols*. Wiley: New York, 1996.
18. DVB-S ETS 300 421, Digital Satellite Transmission Systems, http://www.etsi.org, August 1997.
19. Garret MW. Contributions toward real-time services on packet networks. *Ph.D. Dissertation*, Columbia University, New York, May 1993.
20. Hogg RV, Klugman SA. *Loss Distributions*. Wiley: New York, 1984.
21. Cox DR, Oakes D. *Analysis of Survival Data*. Chapman and Hall, New York, 1984.
22. Alagöz F. Approximations on the aggregated MPEG traffic and their impact on admission control. *Turkish Journal of Electrical Engineering* 2002; **10**(1):73–84.
23. Verbiest W, Pinnoo L, Vosten V. The impact of the ATM concept on video coding. *IEEE Journal on Selected Areas in Communications* 1988; **6**:1623–1632.

AUTHOR'S BIOGRAPHY

Fatih Alagöz, assistant professor in and chairman of the Department of Electrical and Electronics Engineering, Harran University, Turkey. He received his BSc in electrical engineering in 1992, from the Middle East Technical University, Turkey. During 1993, he was a research engineer in a missile manufacturing company, Muhimmatsan AS, Turkey. He obtained his MSc and DSc degrees both in electrical engineering in May 1995 and January 2000, respectively, from the George Washington University, U.S.A. During September 2001–June 2003, he was with the Department of Electrical Engineering, United Arab Emirates University, UAE. His research interests are in the areas of wireless/mobile/satellite networks, teletraffic modelling, performance evaluation and modelling of terrestrial and satellite mobile communications, neural networks, and multi-user detection. He has edited two books, and published more than 30 scholarly papers in selected journals and conferences. Dr Alagoz is a Member of IEEE, and Satellite and Space Communications Technical Committee. He has numerous awards including the YOK Scholarship achieved based on a nationwide selection examination, and the ACM MSWIM'99 Best Paper Award.

