STUDIA INFORMATICA 2003
Volume 24 Number 4 (56)

Jerzy MARTYNA
Institute of Computer Science, Jagiellonian University

SURVEY OF DATA BROADCASTING PROTOCOLS FOR VOD SYSTEMS

Summary. This paper presents a survey of some data broadcasting protocols used in VOD systems. We recall that video servers can provide video data streams to serve multiple customers waiting for the same program (referred to as batching).Typical broadcasting protocols can broadcast video data in such a way that the average client's waiting time is minimal. In this paper, we consider the usefulness of the broadcasting protocols presented in the literature on the subject.

Keywords: Vide-on-Demand (VOD) Systems, broadcasting protocols

PRZEGLĄD PROTOKOŁÓW NADAWANIA DLA SYSTEMÓW TYPU WIDEO NA ŻĄDANIE

Streszczenie. Artykuł dokonuje przeglądu protokołów nadawania używanych w systemach typu *wideo na żądanie* (VOD). Mogą one dostarczać strumieni danych multimedialnych klientom, którzy niejednokrotnie oczekują tych samych programów. Działanie protokołów nadawana dla systemów typu VOD polega na rozsyłaniu danych multimedialnych w taki sposób, by zminimalizować średni czas oczekiwania klienta.

Słowa kluczowe: systemy typu wideo na żądanie, protokoły rozsyłania danych multimedialnych

1. Introduction

More than 75% of today's Internet traffic belongs to Web applications. In spite of this fact, we expect that in the coming years streaming stored video will become the dominant Internet application. Therefore, we must take into account in the design of video streaming all solutions that reduce the costs of video data transmission and the waiting time of users.

A typical VOD system is implemented by client-server architecture [9]. We can implement VOD systems in such networks as next generation Internet [5], ATM networks [12], or satellite networks [3, 13]. In such systems, server and network resources are referred to as logical channels. One logical channel is sufficient to provide the bandwidth demands and continuous delivery requirements of one data video stream.

Depending on how logical channels are utilized, the VOD systems are classified as *interactive* [4] or *broadcasting* [2]. An interactive VOD system emulates the VCR functions (e.g. rewind, forward, pause, etc.). In these systems the growth in the number of clients causes the growth in the number of logical channels. In contrast, the broadcasting VOD systems use logical channels shared by the users. This approach is more appropriate for the transmission of popular data videos. As a result of logical channel sharing some VCR functions may be wasted.

In this paper, we present some broadcasting VOD protocols that reduce all undesirable effects, such as long waiting times, the wasting of VCR functions, etc. They are compared with each other from a system designer's viewpoint.

The remainder of this paper is organized as follows. In Section 2 we provide some mathematical preliminaries describing the logical channels and data broadcasting models, i.e. the theoretic characterization of the transport channel model. In Section 3 we describe in detail some data broadcasting protocols. Finally, Section 4 provides a summary and some conclusions.

2. Some mathematical preliminaries

To analyze the efficiency broadcasting protocols, we introduce a *temporal-bandwidth map*, whose x-axis represents time, and y-axis represents bandwidth. The lower part of the temporal bandwidth is devoted to the corresponding bandwidth. Each logical channel here is represented by its height. The sum of all heights is equal to the server bandwidth requirement. The upper part of the temporal bandwidth map corresponds to each broadcasting segment in the broadcasting area and the upper part is the playout area. An example illustrating one video stream is given in Fig. 1.

By using the temporal-bandwidth map we can analyze the bandwidth eficiency of the VOD server. The shaded area of S_1, S_2, S_3 in the playout area corresponds to the broadcasting of segment S_1, S_2, S_3 in the broadcasting area.

The efficiency of the broadcasting protocols for the VOD system is given by the *broadcasting bandwidth* efficiency [6] as:

$$\text{server bandwidth efficiency} = \frac{\text{playout area of the video segment}}{\text{broadcasting area corresponds to the video segment}}$$

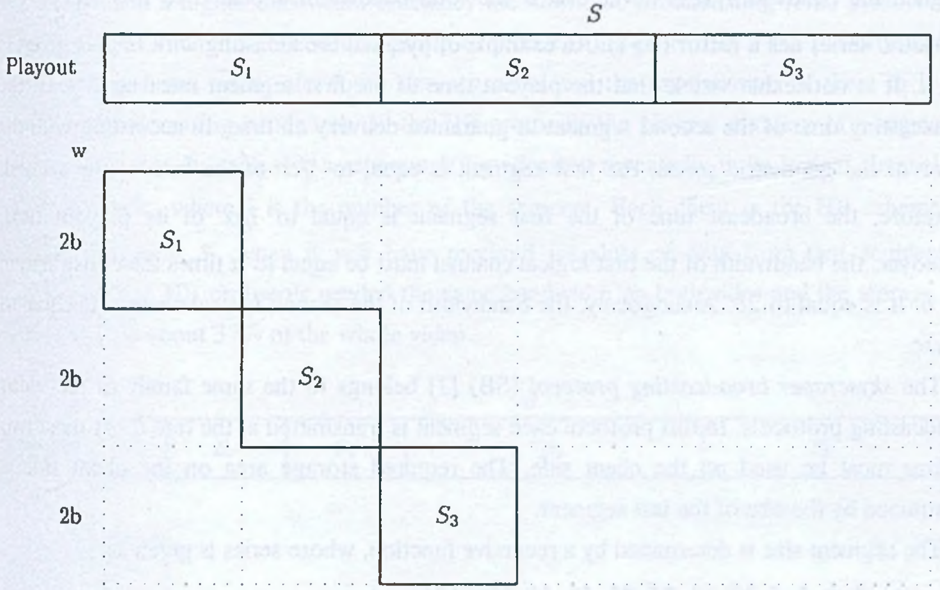

Fig. 1. An example of temporal bandwidth map of broadcasting protocol
Rys. 1. Przykładowe czasowe rozplanowanie pasma transmisji dla protokołu rozsyłania

The above given equation shows that to maximize the server bandwidth efficiency must be reduced by the sum of the bandwidth of each logical channel.

In a more detailed approach we assume that each video is allocated to own logical channel. Assuming that the one video consists of M segments and all segments must be sent through the one logical channel, we can determine the slowest speed of transmission for one logical channel, namely B/M .

3. The survey of data broadcasting protocols for VOD systems

Now, we will present some selected broadcasting protocols. We will give an effective analysis using of the above presented methods.

The *pyramid broadcasting (PB) protocol* [1, 14, 15] belongs to one of the first broadcastings protocols. It can reduce the maximum waiting time in an exponential ratio with respect to the number of logical channels. On the client side buffering storage is needed, which significies a substantial disadvantage. Additionally, all clients can download the next segment at the earliest occurrence. At any moment they use at most two consecutive logical channels.

The activity of the pyramid broadcasting protocol is as follows. Each set of video data is partitioned into K segments of geometrically increasing size. To each logical channel is assigned the bandwidth B/K, where B is the total bandwidth allocated to this video. The geometric series has a factor (α>1). An example of pyramid broadcasting with α=2 is given in Fig. 2. It is noticeable visible that the playout time of the first segment must be at least the broadcasting time of the second segment to guarantee delivery on time. In according with the factor of the geometric series, the first segment is equal to $1/\alpha$ of the size of the second. Therefore, the broadcast time of the first segment is equal to $1/\alpha$ of its playout time. Moreover, the bandwidth of the first logical channel must be equal to α times the consumption rate b. It is equal to $2b$. Analogously, the bandwidth of the second logical channel is equal to $2b$, etc.

The *skyscraper broadcasting protocol* (SB) [7] belongs to the same family of the video broadcasting protocols. In this protocol each segment is transmitted at the rate b. At most two streams must be used on the client side. The required storage area on the client side is constrained by the size of the last segment.

The segment size is determined by a recursive function, whose series is given as:

{1, 2, 2, 5, 5, 12, 12, 25, 25, 52, 52, 101, 101, ... }

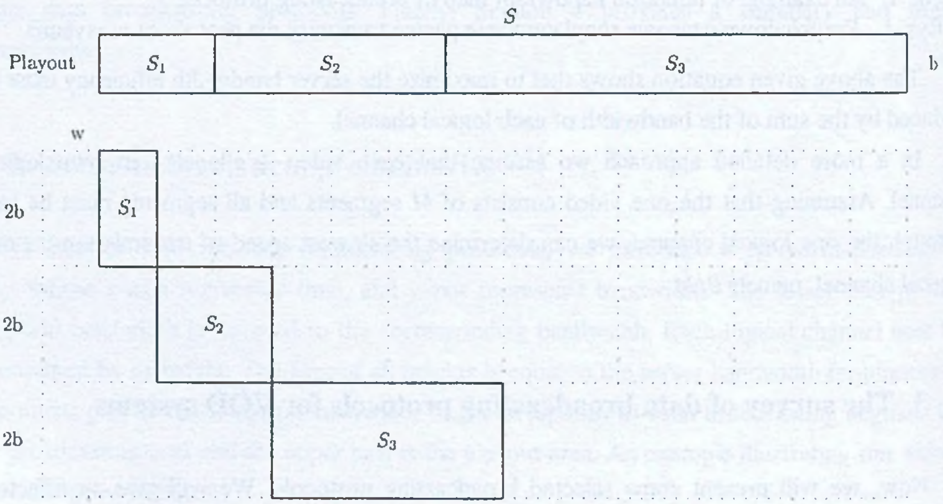

Fig. 2. Temporal bandwidth map of pyramid broadcasting protocol with α=2
Rys. 2. Czasowe rozplanowanie pasma transmisji dla protokołu piramidowego z $\alpha = 2$

It is evident that at the beginning of any segment must end consumption of the current segment. In the SB protocol the bandwidth requirement is not higher than in the PB protocol.

Figure 3 shows how the SB protocol works to achieve the same play time of video as in the PB protocol (see Fig. 2). However, the SB protocol is more efficient than the PB protocol.

To achieve a higher bandwidth efficiency the *harmonic broadcasting (HB) protocol* was proposed [8]. It initiated the second group of broadcasting protocols. They perform through the division of the video into equal size segments and the transmission of them in logical channels of decreasing bandwidth. In the HB protocols the playout duration of a segment is defined as a *slot*. In each slot a segment is broadcasted repeatedly in its logical channel at a bandwidth b/i, where i is the number of the segment. Each client in the HB scheme can consume segment S_i, when it will have received *i-1* slots of data from that segment. In summation, the HB protocols needed the same bandwidth on both sides and the storage area requirement is about 37% of the whole video.

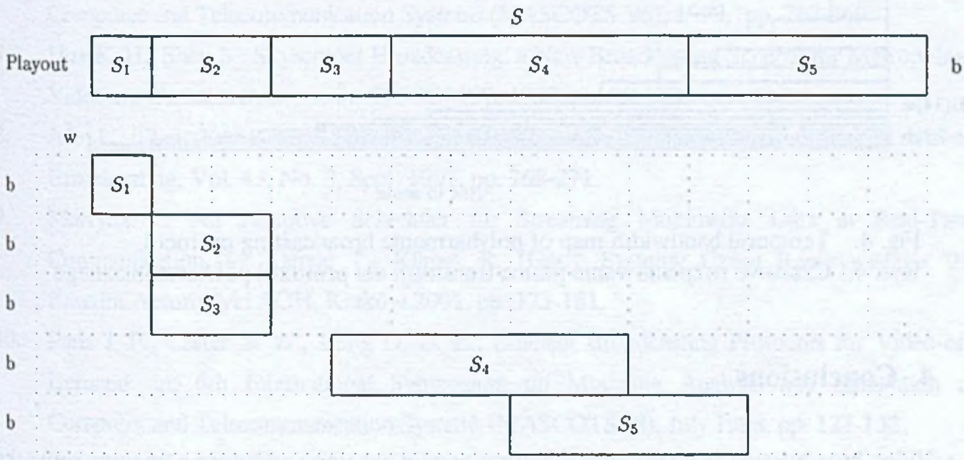

Fig. 3. Temporal bandwidth map of skycraper broadcasting protocol
Rys. 3. Czasowe rozplanowanie pasma transmisji dla protokołu typu „drapacz chmur"

The HB protocol is not always able to provide the video data on time. This is its main fault. To solve this problem Paris et al. proposed the *Caution Harmonic* (CHB) and the *Quasi-Harmonic* (QHB) protocols [10] as well as the *Polyharmonic* (PHB) protocol [11]. The CHB and QHB protocols solved this problem. Despite this fact, these protocols have the same efficiency levels as the HB protocol.

The activity of protocol CHB is as follows. The second and third segments are transformed into the equivalent 1/2 height and 2 slots length, starting from the third segment.

We observe that each segment stream does not stretch as far as in the HB protocol. The PHB protocol works as follows (see Fig. 4). The transmission of the video segment follows immediately, when a request from a client is coming. Thus, the transmission of the video segment is not to held from the beginning. It can be reassembled to form a whole segment after the ending of the transmission. However, the PHB protocol achieves the same maximum access latency as the HB protocol and reduces the waiting time of clients before they can start the service.

Figure 4 shows in the scenario how the PHB protocol works. It can easily be observe that the PHB protocol stretches the segment to transmission with greater efficiency than the previously presented protocols.

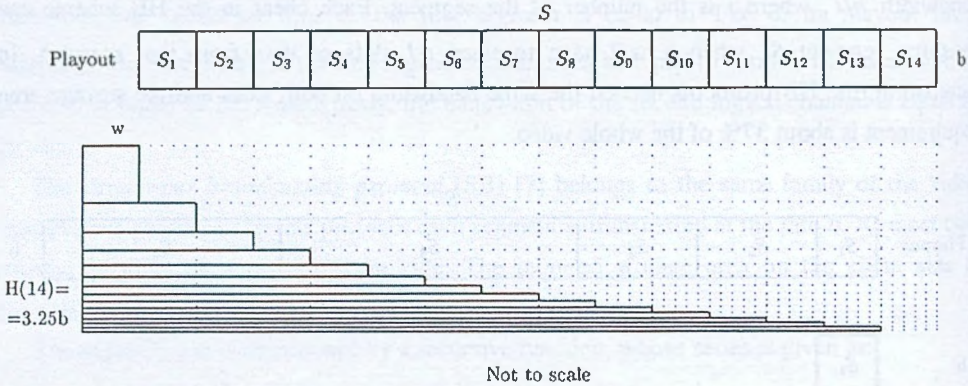

Fig. 4. Temporal bandwidth map of polyharmonic broadcasting protocol
Rys. 4. Czasowe rozplanowanie pasma transmisji dla protokoł poliharmonicznego

4. Conclusions

Video broadcasting is a very important problem in existing and future computer networks. In this paper, we have presented a survey of the currently used video broadcasting protocols. In all protocols it was assumed that the number of logical channels is fixed and the bandwidth will be assigned to a video throughout the broadcast. If demand for video changes, then additional logical channels will be needed or disruption will be experienced by existing clients. Therefore, we will design new broadcasting protocols with fully adaptable properties.

REFERENCES

1. Aggarwal C. C., Wolf J. L., Yu P. S.: A Permutation-Based Pyramid Broadcasting Scheme for Video-on-Demand Systems. in: Proc. of the IEEE International Conference on Multimedia Computing and Systems '96, Hiroshima, Japan, June 1996, pp. 118-126.

2. Atzori L., Natale F. D., Gregorio M. D., Giusto D. D.: Multimedia Information Broadcasting Using Digital TV Channels. IEEE Transactions on Broadcasting, Vol. 43, No. 3, 1997, pp. 242-251.
3. Chang Y. H., Coggins D., Pitt D., Skellern D.: An Open-System Approach to Video on Demand. IEEE Communications Magazine, Vol. 32, No. 5, 1994, pp. 68-80.
4. Deloddere D., Verbiest W., Verhille H.: Interactive Video on Demand. IEEE Communications Magazine, Vol. 32, May 1994, pp. 82-88.
5. Hou Y. T., Wu D., Li B., Hamada T., Ahmad I., Chao H. J.: A Differential Services Architecture for Multimedia Streaming in Next Generation Internet. Computer Networks, Vol. 32, 2000, pp. 185-209.
6. Hu A., Nikolaidis I., van Beek P.: On the Design of Efficient Video-on-Demand Broadcast Schemes. in: Proc. of 7th International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS '96), 1999, pp. 262-269.
7. Hua K. H., Sheu S.: Skyscraper Broadcasting: a New Broadcasting Scheme for Metropolitan Video-on-Demand Systems. in: SIGCOM'97, 1997, pp. 89-100.
8. Juhn L., Tseng L.: Harmonic Broadcasting Protocols for Video on Demand. IEEE Trans. on Broadcasting, Vol. 43, No. 3, Sept. 1997, pp. 268-271.
9. Martyna J.: An Adaptive Scheduler for Streaming Multimedia Data in Real-Time Communication. in: Szmuc T., Klimek R. (Eds.): Systemy Czasu Rzeczywistego '01, Katedra Automatyki AGH, Kraków 2001, pp. 173-181.
10. Paris J.-F., Carter S. W., Long D. D. E.: Efficient Broadcasting Protocols for Video-on-Demand. in: 6th International Symposium on Modeling Analysis and Simulation of Computer and Telecommunication Systems (MASCOTS'98), July 1998, pp. 127-132.
11. Paris J.-F., Carter S. W., Long D. D. E.: A Low Bandwidth Broadcasting Protocol for Video on Demand. in: Proc. of IEEE International Conference on Computer Communications and Networks (IC3N'98).
12. Reibman A. R., Berger A. W.: Traffic Descriptors for VBR Video Telecon-ferencing over ATM Networks. IEEE/ACM Trans.on Networking, Vol. 3, No. 3, June 1995, pp. 329-339.
13. Sincoskie W. D.: System Architecture for a Large Scale Video on Demand Service. Computer Networks and ISDN Systems, Vol. 22, 1991, pp. 565-570.
14. Viswanathan S., Imieliński T.: Pyramid Broadcasting for Video on Demand Service. Multimedia and Networking Conference, Vol. 2417, 1995, pp. 66-77.
15. Viswanathan S., Imieliński T.: Metropolitan Area Video-on-Demand Service Using Pyramid Broadcasting. Multimedia Systems, Vol. 4, 1996, pp. 197-208.

Recenzent: Dr inż. Mirosław Skrzewski

Wpłynęło do Redakcji 10 kwietnia 2003 r.

Omówienie

W pracy dokonano przeglądu stosowanych protokołów rozsyłania segmentów danych multimedialnych. Protokoły te są implementowane w serwerach typu wideo na żądanie. Między innymi przedstawiono protokoły rozsyłania: piramidowy, typu „drapacz chmur" oraz poliharmoniczny. Opisano ich działanie oraz podano ich charakterystyczne własności.

Adres

Jerzy MARTYNA: Institute of Computer Science, Jagiellonian University, ul. Nawojki 11, 30-072 Cracow, Poland, martyna@softlab.ii.uj.edu.pl