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A SCHEDULING METHOD FOR WAITING TIME REDUCTION IN AREA-BASED BROADCASTING CONSIDERING LOADING TIME

YUSUKE GOTOH

Okayama University, Okayama
gotoh@cs.okayama-u.ac.jp

TOMOKI YOSHIHISA

Cybermedia Center, Osaka University, Osaka
yoshihisa@cmc.osaka-u.ac.jp

Due to the recent popularization of digital broadcasting systems, clients can watch several types of contents. In addition, area-based broadcasting, which uses the bandwidth that is not used in radio broadcasting, has attracted great attention. In area-based network environments, a server can deliver continuous media data such as audio and video in a limited area. Clients can get improved convenience by receiving such information as shopping coupons and community news based on their watching area using their own nodes. In area-based broadcasting, many clients watch content in the delivery area. Although servers can concurrently deliver data to many clients, they have to wait until their data are broadcast. To reduce waiting times, many studies employ the division-based broadcasting technique, which reduce waiting times by dividing the data into several segments and frequently broadcasting the precedent segments. These scheduling methods make a broadcast schedule that considers the situation in actual network environments. When the server makes a broadcast schedule in area-based broadcasting, it needs to consider both the loading times of the highlight and main scenes. In broadcasting, since the playing time of the commercial contents is predetermined, clients watch them during the loading time. Therefore, the server needs to make the broadcast schedule based on the consumption rate and the number of channels by setting both the loading times of the highlight and main scenes. In this paper, we propose a scheduling method that considers the loading time for area-based broadcasting. In our scheduling method, since the server makes a broadcast schedule using a different ratio of dividing the data for highlight and main scenes, the waiting time is reduced effectively.

Key words: Area-based broadcasting, continuous media data, loading time, scheduling, waiting time

1 Introduction

Due to the recent popularization of digital broadcasting systems, clients are offered several types of contents [1]. In addition, area-based broadcasting using the bandwidth that is not used in radio broadcasting has attracted great attention. In area-based broadcasting, interference among channels can be reduced by controlling the output of radio waves and limiting the range for receiving data. The server can deliver such continuous media data as audio and video in a limited area. Clients can have improved convenience by receiving such information as shopping coupons and community news based on their watching area that uses their mobile devices. In the case of Japan, the service providers can easily start data delivery within about a 200-meter radius [2].

The server can deliver a program and advertisements effectively to many clients in a limited area, and clients can watch programs on their devices. However, since users move frequently, programs might be interrupted when they move outside of the broadcast area. Therefore, to maintain users' interest and encourage them to stay as long as possible in the area, it is effective to deliver programs using a digest delivery, through which clients continuously watch both highlight and main scenes. In digest delivery, clients first watch the highlight scene in the area-based broadcasting area. If they are interested in it, they can watch the main scene continuously.

In area-based broadcasting, many clients watch content in the delivery area. Although servers can concurrently deliver data to many clients, they have to wait until their data are broadcast. To reduce waiting times, many studies employ the division-based broadcasting technique, which reduces waiting times by dividing the data into several segments and frequently broadcasting the precedent segments. These scheduling methods make a broadcast schedule based on the situation in actual network environments.

When the server makes a broadcast schedule in area-based broadcasting, it needs to consider both the loading times of the highlight and main scenes. In actual broadcast services, when the server delivers the content in area-based broadcasting, clients watch commercial contents during the loading time. Therefore, the server needs to set the ratio of each segment and makes a broadcast schedule based on the consumption rate and the number of channels by setting both the loading times of the highlight and the main scenes.

In this paper, we propose a scheduling method to reduce waiting times by considering the loading times for area-based broadcasting. In our scheduling method, since the server makes a broadcast schedule using a different ratio of dividing the data for the highlight and the main scenes, clients can watch the content to the end.

The remainder of this paper is organized as follows. Our basic idea in area-based broadcasting is explained in Section 2. In Section 3, we explain the mechanism of waiting time in broadcasting. Related works are introduced in Section 4. In Section 5, we describe our proposed method and evaluate it in Section 6. Finally, we conclude in Section 7.

2 Area-based Broadcasting

2.1 Basic Idea

In this section, we explain area-based broadcasting whose assumed structure is shown in Figure 1. In area-based broadcasting, interference among channels can be reduced by controlling the output of radio waves and limiting the range in which data can be received. The server can deliver continuous media data such as audio and video in a limited area. Users get improved convenience by receiving information based on their watching area using their own nodes. Examples of such situations follow:

(1) At sporting events, users can acquire information of their favorite teams and game situations in real time.

(2) In the cities, users can get coupons at their favorite shops and watch highlight scenes of their favorite movies.

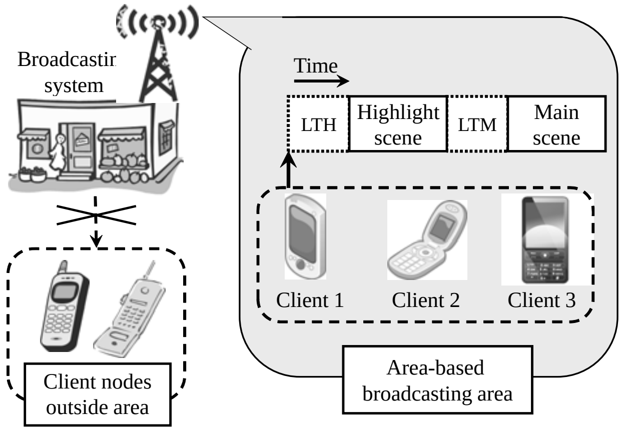

Figure 1 Assumed structure of area-based broadcasting.

The server can deliver a program and advertisements effectively to many clients in a limited area, and clients can watch the program on their devices. However, since users move frequently, programs might be interrupted when they move outside of the broadcast area.

2.2 Delivering Data in Area-based Broadcasting

To maintain users' interest and encourage them to stay as long as possible in the area, it is effective to deliver programs using digest delivery. Clients first watch a highlight scene in the area-based broadcasting area. If they are interested in the highlight scene, they can continuously watch the main scene.

In area-based broadcasting, there are two types of waiting times. The waiting time that occurs from selecting the highlight scene to starting to play it is called the ``loading time for playing highlight scenes" **(LTH)**. The server can set an upper limit for LTH. The waiting time that occurs from requiring the program to starting to play it called the ``loading time for playing main scene" **(LTM)**. LTH occurs when acquiring a user's selection. On the other hand, LTM occurs when starting to play the program.

3 Waiting Time in Broadcasting

3.1 Mechanism for Waiting Time

In this subsection, we explain the mechanism for generating the waiting time. In webcasts, there are mainly two types of delivery systems: VoD and broadcasting.

We calculated the waiting times for VoD and broadcasting systems. The situations that cause waiting times in both systems are shown in Figure 2. In the VoD system, the server starts delivering data sequentially based on client requests. Waiting times under VoD systems are roughly equal to the receiving times. When the server repetitively broadcasts continuous media data, clients have to wait until the first portion of the data is broadcast.

The broadcast schedule under a simple method is shown in Figure 3. Suppose a server broadcasts MPEG2-encoded movie data using all of the available bandwidth that has a 1.5 Mbps wireless LAN

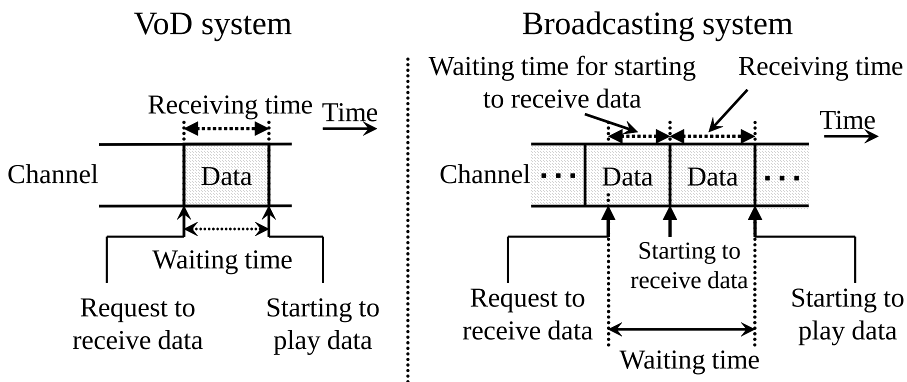

Figure 2 Waiting time in VoD and broadcasting systems.

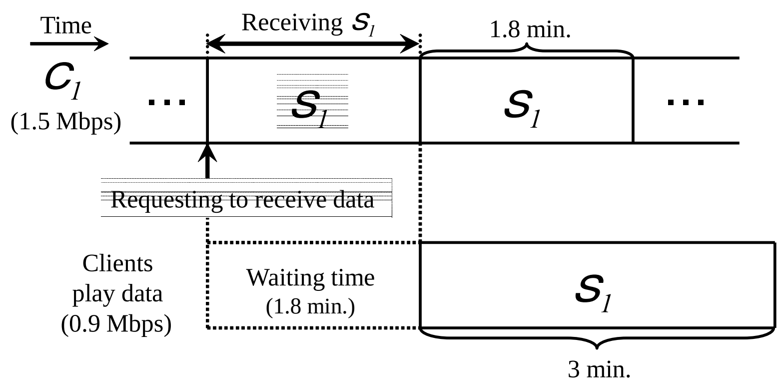

Figure 3 Example of broadcasting situation under simple method.

network. The consumption rate is 0.9 Mbps, and the playing time is 3 min. During the broadcasting, the server delivers data repetitively to many clients. When a client receives data from the server, waiting time occurs. When the server broadcasts contents data repetitively, clients have to wait until the first part of the data is broadcast. In Figure 3, the maximum waiting time is the broadcast cycle: 1.8 min.

To reduce the waiting time, many methods employ the division-based broadcasting technique, which reduces the waiting time by dividing the data into several segments and frequently broadcasting precedent segments. In division-based broadcasting, these methods suppose such data delivery as radio wave broadcasting and Internet multicast.

3.2 Scheduling Method in Division-based Broadcasting

Next, we explain the waiting time for broadcasting data that are divided into several segments. In division-based broadcasting, since the data are divided into several segments, they must be scheduled without interrupting the continuous play of clients. In the conventional methods, clients can play the data without interruption based on the available bandwidth and several channels.

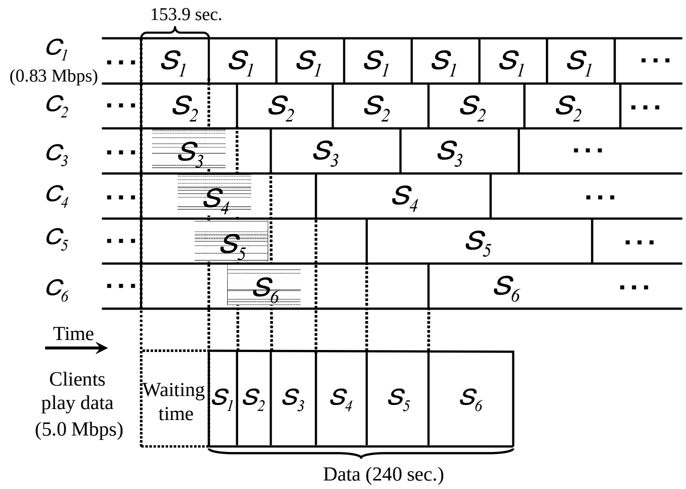

Figure 4 Example of division-based broadcasting under BE-AHB method.

An example of division-based broadcasting is shown in Figure 4. It uses the Bandwidth Equivalent-Asynchronous Harmonic Broadcasting (BE-AHB) method [3] to explain the problem of waiting times. This example divides the data into six segments. The playing time is 240 sec. The data are divided into six segments: S_i (i = 1, …, 6). When the available bandwidth for the clients is 5.0 Mbps, the bandwidth of each channel is 5.0 / 6 = 0.83 Mbps. The consumption rate is 5.0 Mbps. Under the BE-AHB method, when the total playing time is 60 + 180 = 240 sec, the playing time of S_1 is 25.5 sec, S_2 is 29.8 sec, …, and S_6 is 55.3 sec. The server repetitively broadcasts S_i by broadcast channels C_i . Clients can play each segment after receiving it. While playing the data, clients receive the broadcast data and store them in their buffers. In this case, the clients can play the data continuously until they are finished, even if they start playing them immediately after completely receiving S_1. When clients finish playing S_1, they have finished receiving S_2 and can play it continuously. In addition, when they are finished playing S_3, they have finished receiving S_4 and can play it continuously. In this case, the waiting time is 25.5 × 5.0 / 0.83 = 153.9 sec, which is the same as the time needed to receive only S_1. In the simple method, since the server broadcasts data without dividing them, the waiting time is 240 × 5.0 / 5.0 = 240 sec. Therefore, (240 - 153.9) / 240 × 100 = 35.9 %, which is shorter than the simple method.

3.3 Scheduling Method in Area-based Broadcasting

In area-based broadcasting, the broadcast schedule under the BE-AHB method is shown in Figure 5. We set LTM to 30 sec. The server broadcasts the partitioned data repetitively under the BE-AHB method using both the highlight and main scenes. In area-based broadcasting, LTM occurs while playing the program. On the other hand, in the BE-AHB method, since clients play segments without interruption, it does not make a broadcast schedule based on LTM and fails to effectively reduce the waiting time.

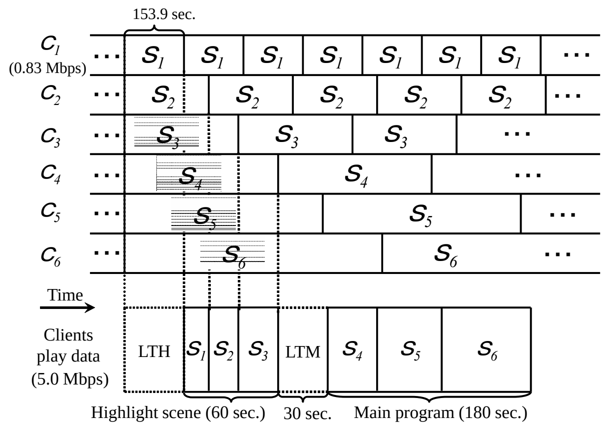

Figure 5 Example of area-based broadcasting under BE-AHB method.

4 Related Works

4.1 Area-based Broadcasting

In Japan, several services have been proposed that use area-based broadcasting. Area One segment-Broadcasting (Area One-Seg) [4] is a broadcasting service that delivers data by applying one-segment technology in a limited one-kilometer radius area. One-segment technology is used for terrestrial digital broadcasting in Japan. By delivering content suitable for the place and time, the server can deliver information effectively in such places such as stations or stadiums where many people gather.

Spot one-segment broadcasting [5] is a service in which the server can broadcast data to specific users. In this scheme, everybody can manage the broadcast service without a broadcast license. However, the electric waves in one-segment broadcasting are weaker than in Area One-Seg, and the transmission range is limited to about a one-meter radius. In these broadcasting systems, no broadcast scheduling has been proposed that reduces waiting times.

4.2 Division-based Broadcasting

Several methods to reduce waiting times have been proposed in continuous media data broadcasting [6, 7, 8, 9, 10, 11, 12, 13]. These methods reduce waiting times by dividing the data into several segments and producing an efficient broadcast schedule.

In Heterogeneous Receiver-Oriented Broadcasting (HeRO) [14], the data are divided into different sizes. Let J be the data size for the first segment. The data sizes for the remaining segments are J, $2J$, 2^2J, …, $2^{K-1}J$. However, since the data size of the K^{th} channel becomes half of the data, clients may experience waiting and interruptions.

In BroadCatch [15], the server divides the data into 2^{K-1} segments of equal size and broadcasts them periodically using K channels. The bandwidth for each channel is the same as the data bit rate. By adjusting K based on the available bandwidth for the clients, waiting times are effectively reduced. However, since the available bandwidth is proportional to the number of channels, when an upper limit exists in the server's bandwidth, the server might not be able to acquire enough channels to broadcast the data.

In Harmonic Broadcasting (HB) [16], the data are separated into S_1, …, S_N of equal size. The server sets C_1, …, C_N channels based on the available bandwidth and schedules S_1, …, S_N. The client can play S_1, …, S_N without interruption using C_1, …, C_N. For example, when the server broadcasts continuous media data whose playing time is 60 min and whose consumption rate is 5.0 Mbps using 24 Mbps, which is identical to that under digital broadcasting systems, we need 67 channels.

In Asynchronous Harmonic Broadcasting (AHB) [3], waiting times are reduced more than the HB method by scheduling playing unit times, such as Group of Pictures (GOP) in MPEG2 or frames in MP3. Since the server divides the data of each playing unit time, the number of channels is the same as the number of playing units. For example, when the server broadcasts a piece of continuous media data whose playing time is 60 min and whose consumption rate is 5.0 Mbps using 24 Mbps, which is identical to that under digital broadcasting systems, the number of channels is 6,000. The BE-AHB method is an extended version of the AHB method, where continuous media data are separated by a fixed data size. The server can reduce the necessary number of channels, which is more realistic than the original AHB method.

We previously proposed scheduling methods to reduce waiting times for division-based broadcasting [17, 18]. These methods make a schedule using single bits of continuous media data. In addition, our assumed structure is area-based broadcasting.

5 Related Works

5.1 Basic Idea

We propose a scheduling method in area-based broadcasting called the Area-based Contents Broadcasting (ACB) method. In this paper, we propose a scheduling method that considers both the loading times of highlight and main scenes in area-based broadcasting. In the ACB method, the server makes a broadcast schedule using a different ratio that divides the data for the highlight and the main scenes. Although the conventional BE-AHB method makes a broadcast schedule considering LTH only, the ACB method makes it considering both LTH and LTM.

5.2 Assumed Environment

Our assumed system environment is listed below.

(1) Clients sequentially play the highlight and main scenes.

(2) Waiting time occurs when the server starts to play the highlight and main scenes.

(3) The bandwidth is stable while broadcasting the data.

(4) Clients can start playing a segment after they have completely received it.

(5) The server broadcasts segments repetitively using multiple channels.

(6) Once clients start playing the data, they can play them without interruption.

(7) Clients have an adequate buffer to store the received data.

Table 1 Formulation symbols

Valuable	Explanation
r	Consumption rate
D_1	Data size of highlight scene
D_2	Data size of main scene
N_1	Number of segments for D_1
N_2	Number of segments for D_2
$s_{i\text{-}j}$	j^{th} subsegment in D_i , i =1, 2 || j =1, ..., N
C_i	Available bandwidth to broadcast D_i
b_i	Available bandwidth to broadcast $s_{i\text{-}j}$
T_i	Playing time of D_i
$t_{i\text{-}j}$	Playing time of $s_{i\text{-}j}$
B	Total available bandwidth of server
α	Maximum LTH
β	Maximum LTM

5.3 Modeling to Reduce Waiting Times

We developed an expression to reduce the waiting times for continuous media data in area-based broadcasting. The formulation values are summarized in Table 1.

In continuous media data broadcasting, we need to schedule segments based on the receiving time of the first segment and the interruption time between finishing the highlight scene and starting the main scene. Actually, many network structures exist for division-based broadcasting systems. However, since the number of patterns is excessive, evaluating the performance of our proposed method for all of them is unrealistic. Therefore, in this paper, we use the network configuration shown in Figure 1. Although the practical programs do not always match these patterns, there are enough to show the effectiveness of our proposed method.

In our proposed method, the server reduces waiting times by calculating the available bandwidth of each broadcast channel to minimize the average waiting time. By including LTH and LTM in the receiving time of the data, the server can lengthen the receiving time of the main scene and reduce the necessary bandwidth for delivering the highlight scene. By considering LTH and LTM, calculating the available bandwidth of each channel becomes slightly more complex. However, the available bandwidth of each channel can be calculated by a simple simulation.

5.4 Scheduling Process

In this section, we explain the details of the ACB method, which divides the total available bandwidth of the server into several channels. Clients can reduce waiting times effectively by scheduling segments using several channels.

The scheduling process continues as follows. The notation is defined in Table 1. We explained the basic idea of our scheduling process in Subsection 5.3.

1. According to N_i , D_i is separated into $s_{i\text{-}1}, \ldots, s_{i\text{-}Ni}$, for which the playing time is $t_{i\text{-}1}, \ldots, t_{i\text{-}Ni}$.

2. $s_{1\text{-}1}, \ldots, s_{1\text{-}Ni}$ must be scheduled so that the clients, which can concurrently receive data from N_i channels, can play them continuously. After the finishing time of LTH, clients must play $s_{1\text{-}1}$. Since the

playing time of $s_{1\text{-}1}$ is b_1 / r, $s_{1\text{-}2}$ must play until it finishes receiving $s_{1\text{-}1}$, which is $(1 + b_1 / r)$. Next, the clients can wait to start $s_{2\text{-}1}$ until the finishing time of LTM. In addition, $t_{2\text{-}j}$ is calculated by considering $t_{2\text{-}1}$. Therefore, when $t_{1\text{-}1}$ is α and $t_{2\text{-}1}$ is $\alpha + T_1 + \beta$, T_1 and T_2 obtain the following equation:

$$T_1 = \alpha \times \left\{ \left(1 + \frac{b_1}{r}\right)^{N_1} - 1 \right\} . \tag{1}$$

$$T_2 = (\alpha + T_1 + \beta) \times \left\{ \left(1 + \frac{b_2}{r}\right)^{N_2} - 1 \right\} . \tag{2}$$

3. Based on formulas (1) and (2), b_1 and b_2 are calculated as follows:

$$b_1 = \left(\sqrt[N_1]{\frac{T_1}{\alpha} + 1} - 1 \right) \times r . \tag{3}$$

$$b_2 = \left(\sqrt[N_2]{\frac{T_2}{(\alpha + T_1 + \beta)} + 1} - 1 \right) \times r . \tag{4}$$

4. Decide C_i based on $t_{i\text{-}j}$, which was calculated in Step 3. As shown in Subsection 5.5, we can calculate C_i in the simple computational simulation.

5.5 Simple Example to Reduce Waiting Time

In the ACB method, when the available bandwidth of the highlight scene is C_1 and the main scene is C_2, the broadcast is scheduled so that clients who can receive data from C_i can play them without interruption even if they start playing them just after receiving the first segment of each content $s_{1\text{-}1}$ and $s_{2\text{-}1}$. The waiting times for the clients that receive data using a larger bandwidth than C_i cannot be improved. Let C_i^* be the value of optimal C_i. Then we have to find the value of C_i^* that minimizes the average waiting time.

When C_i is the same as the available bandwidth given by the ACB method, it becomes optimal because the broadcast schedule was set up to receive the next segment just before the client finishes playing the current segment. Otherwise, the broadcast schedule is not optimal. If we call the state where there is no buffer in the meantime a starvation, we have to make a broadcast schedule to minimize starvations as much as possible. The deadline denotes the time to finish playing the current segment.

Here, the procedure for calculating C_i^* continues as follows:

(1) Produce the broadcast schedule for all C_i.

(2) Calculate the waiting times for all the produced broadcast schedules.

(3) Find C_i^* that gives the minimum average waiting time.

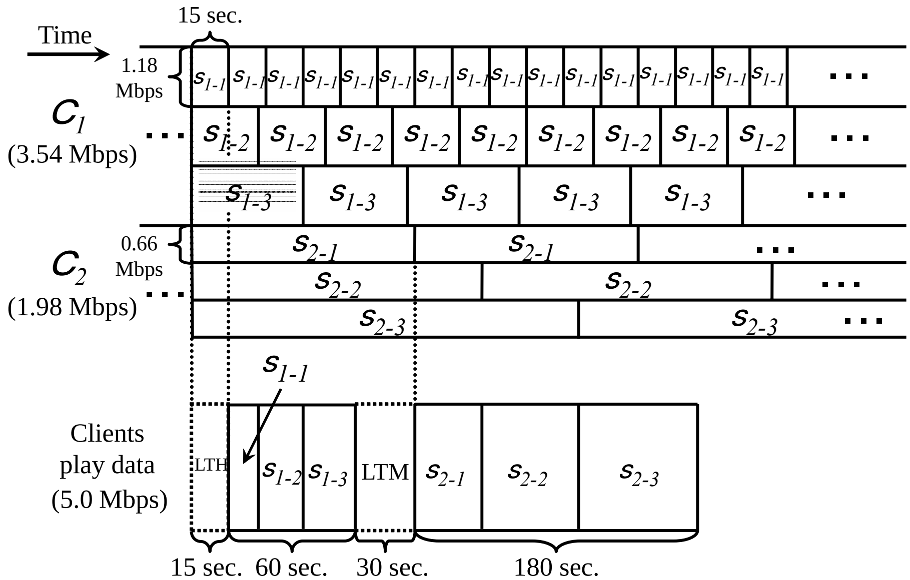

Figure 6 Example of broadcast schedule under ACB method.

5.6 Implementation

The server broadcasts segments following the procedure explained in Subsection 5.4. Continuous media data are partitioned into several segments by the broadcast schedule in the ACB method, where the bandwidth of each subchannel is adjusted based on the available bandwidth of the server. In addition, the server broadcasts data repeatedly based on the broadcast schedule.

When the clients require continuous media data from the server, they start to receive them from several broadcast channels. Clients start playing the highlight scene after completely receiving s_{1-1}. They receive the data while playing them and store them in their buffer. Clients continuously play s_{1-2}, which is stored in their buffer after finishing the playing of s_{1-1}. Clients can play continuous media data without interruption until they have completely finished receiving them.

For example, a situation that delivers data under the ACB method is shown in Figure 6. The number of segments is three, and the consumption rate is 5.0 Mbps. The playing time of the highlight scene is 60 sec, that of the main scene is 180 sec, α is 15 sec, and β is 30 sec.

After starting to receive the data, the client starts playing them after receiving s_{1-1}. In this case, when α is 15 sec, since the receiving time of s_{1-1} is also 15 sec, the bandwidth of b_1 is 1.18 Mbps. When β is 30 sec, the bandwidth of b_2 is 0.66 Mbps. Therefore, the total available bandwidth is: $(1.18 + 0.66) \times 3 = 5.52$ Mbps. Since the client finishes receiving s_{2-1}, it can play s_{2-1} without interruption after finishing LTM. In Figure 6, the waiting time under the ACB method is reduced $(197.6 - 72.1) / 197.6 \times 100 = 63.5$ %, compared to the BE-AHB method.

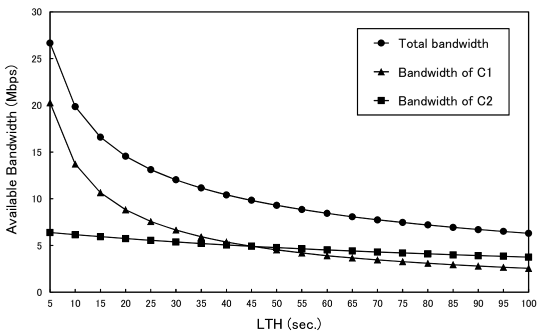

Figure 7 Available bandwidth and loading time of highlight scene.

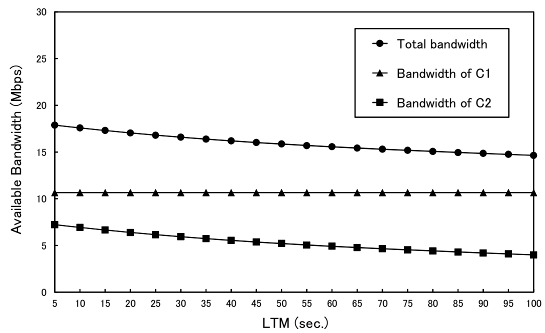

Figure 8 Available bandwidth and commercial time of main scene.

6 Related Works

6.1 Basic Idea

In this section, we evaluate the performance of the ACB method with a computational simulation. Actually, there are many network structures for continuous media data broadcasting. However, since the number of patterns is excessive, evaluating the performance of our proposed method for all these patterns was not realistic. Therefore, we used the network configuration in Figure 1 and compared the total waiting times with the BE-AHB method [3] and HeRO [14].

6.2 Effect of Bandwidth

6.2.1 Loading Time of Highlight Scene

In area-based broadcasting, since the available bandwidth accepted by the server and users varies, we calculate the available bandwidth under different loading times.

The result is shown in Figure 7. The horizontal axis is the loading time of the highlight scene. The vertical axis is the available bandwidth. The playing time of the highlight scene is 60 sec., and that of the main scene is 180 sec. The loading time of the main scene is 30 sec., and the consumption rate is 5.0 Mbps.

In Figure 7, the available bandwidth is reduced by increasing of the loading time of the highlight scene. When its loading time exceeds 45 sec., the available bandwidth of C_1 is less than that of C_2. When the loading time of the highlight scene increases, since the receiving time of $s_{1\text{-}1}$ increases, the available bandwidth of C_1 is reduced.

6.2.2 Loading Time of Main Scene

In area-based broadcasting, the server can set the optimal available bandwidth by making a broadcast schedule effectively based on the loading time of the main scene as a commercial. To confirm the availability of the broadcast scheduling, we calculate the available bandwidth under different loading times.

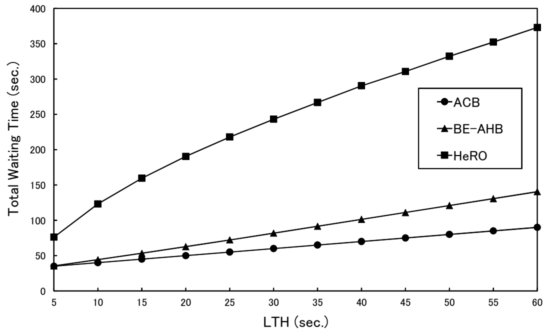

Figure 9 Waiting and loading times of highlight scene.

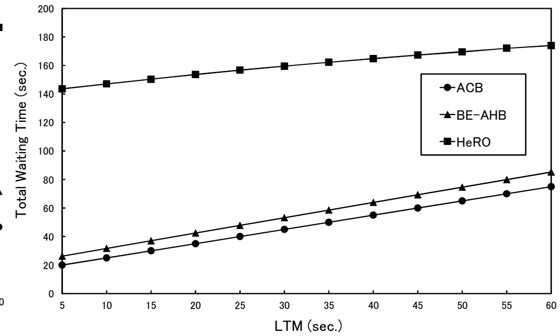

Figure 10 Waiting and commercial times of main scene.

The result is shown in Figure 8. The horizontal axis is the loading time of the main scene. The vertical axis is the available bandwidth. The playing time of the highlight scene is 60 sec., and that of the main scene is 180 sec. The loading time of highlight scene is 15 sec., and the consumption rate is 5.0 Mbps.

In Figure 8, when the loading time of the main scene increases, since the receiving time of $s_{2\text{-}1}$ increases, the available bandwidth of C_2 is reduced. In addition, the available bandwidth of C_1 is not changed because the receiving time for each segment of D_1 is not changed.

6.3 Effect of Waiting Time

6.3.1 Loading Time of Highlight Scene

In area-based broadcasting, since the waiting time accepted by the users varies, we calculate it under different loading times.

The result is shown in Figure 9. The horizontal axis is the loading times of the highlight scenes. The vertical axis is the waiting times. The playing time of the highlight scene is 60 sec., and that of the main scene is 180 sec. The loading time of the main scene is 30 sec. and the consumption rate is 5.0 Mbps.

In Figure 9, the average waiting time under the ACB method is shorter than the conventional BE-AHB method and HeRO. For example, when the loading time of the highlight scene is 45 sec., the waiting time is 75 sec. under the ACB method, 101.5 sec. under the BE-AHB method, and 310.7 sec. under HeRO. The average waiting time under the ACB method is reduced by 26.1 % compared to the BE-AHB method and 75.9 % compared to HeRO.

6.3.2 Loading Time of Highlight Scene

We calculated the waiting time under different loading times of the main scene. The result is shown in Figure 10. The horizontal axis is the loading time of the main scene. The vertical axis is the waiting time. The playing time of the highlight scene is 60 sec., and that of the main scene is 180 sec. The loading time of the highlight scene is 15 sec., and the consumption rate is 5.0 Mbps.

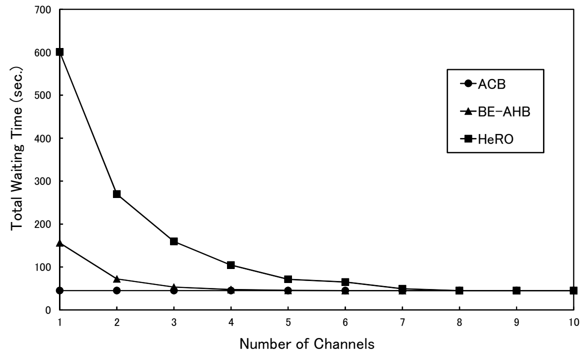

Figure 11 Waiting time and number of channels.

In Figure 10, the average waiting time under the ACB method is shorter than the conventional BE-AHB method and HeRO. For example, when the loading time of the main scene is 30 sec., the waiting time is 45 sec. under the ACB method, 53.2 sec. under the BE-AHB method, and 159.5 sec. under the HeRO. The average waiting time under the ACB method is reduced by 15.4 % compared to the BE-AHB method and 65.5 % compared to HeRO.

6.3.3 Number of Channels

Finally, we calculated the waiting times under a different number of channels. The result is shown in Figure 11. The horizontal axis is the number of channels. The vertical axis is the total waiting time. The playing time of the highlight scene is 60 sec., and that of the main scene is 180 sec. The loading time of the highlight scene is 15 sec., the loading time of the main scene is 30 sec., and the consumption rate is 5.0 Mbps.

In Figure 11, the waiting time is reduced by increasing of the number of channels. When the number of channels exceeds six, the average waiting times under the ACB and BE-AHB methods are the same. In addition, when the number of channels exceeds 8, the average waiting times under all the methods are the same.

7 Conclusion

In this paper, we proposed a scheduling method for area-based broadcasting based on loading times. In our proposed method, by producing an effective broadcast schedule considering both the loading times of highlight and main scenes, we can reduce the waiting times. In our evaluations, we showed the available bandwidth for which the average waiting time has a minimum value by computational simulation. Also, we confirmed that the average waiting time decreased more than the BE-AHB method and HeRO.

A future direction of this study will involve creating a scheduling method in broadcasting selective contents in which users watch several content streams while selecting them [18].

Acknowledgments

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