Abstract

Periodic broadcasting is known as an efficient technique to support near Video-on-Demand services for delivering popular videos, since it can reduce the bandwidth requirement for transmitting streaming video to simultaneous viewers. The channel transition problem is an issue to be concerned about the variability of popularity of video in periodic broadcasting. In this paper, we present a novel channel transition scheme over the fast broadcasting (FB) scheme. Our proposed scheme has less bandwidth waste than the existing seamless channel transition (SCT) scheme. In addition, no extra service delay and client buffer are needed in our scheme.

1. Introduction

Video-on-Demand (VoD) system is typically a platform to provide real-time multimedia delivery services. Clients can watch desired videos at desired time without waiting. To access a VoD program, the client only requires a set-top box connected to the television set. The set-top box allows the client to navigate the electrical program guide and handle the reception and display of the video once the client has made a choice.

The cost to distribute a video is expensive. With a MPEG-2 video, a stream of video data will take a bandwidth of at least 4 Megabits per second (Mb/s). A VoD server will be limited by its bandwidth capacity. Therefore, the near VoD technology was proposed. In near VoD services, clients may have to wait by some delay time because a video is broadcasted over several channels with a periodical cycle. The number of broadcasting channels is due to the maximum service delay, not the number of requests. Thus, it is more suitable for distributing hot video programs.

Many near VoD broadcasting techniques have been proposed, such as harmonic broadcasting [1], staircase broadcasting [2], fast broadcasting [3], pyramid [4], skyscraper [5], Pagoda [6], JAS/stream-bundling [7] and so on. During these broadcasting schemes, the fast broadcasting (FB) is popular by its high practicability.

The channel transition problem is one of the issues to be concerned in periodic broadcasting. The channel transition may be performed according to the variation of popularity of a video. The service delay of a popular movie should be shortened to satisfy a large number of clients. Otherwise, if a movie is no longer popular, part of the assigned channels can be released for other movies.

The “seamless” property of a channel transition scheme represents that the adjustment of channels should not break off the services for the clients. A seamless channel transition (SCT) scheme over the fast broadcasting was proposed in [8]. This transition scheme employed a “data padding” strategy to enlarge the original video to be of suitable size before performing the transition process. Thus it may cause some considerable overheads, such as regular bandwidth waste, longer service delay and larger client buffer. In this paper, we adopt another strategy due to some constructive observations. The new channel transition scheme is more concise and needs fewer overheads since the padding is unnecessary.

The rest of this paper is organized as follows. Section 2 introduces the fast broadcasting scheme and the current channel transition scheme based on FB. In Section 3, we introduce our proposed channel transition scheme. Some comparisons between two schemes are illustrated in Section 4. Finally a conclusion is given in Section 5.

2. Related Works

2.1 The fast broadcasting (FB) scheme

Suppose \( k \) channels are allocated for a video with length \( L \) in FB. The sequence \( \{C_1, C_2, \ldots, C_k\} \) represents the \( k \) channels correspondingly. The video is equally divided into \( N \) segments, where \( N = 2^k - 1 \). Let \( S_i \) denotes the \( i^{th} \) segment of the video, the entire video can be constituted as \( S_1, S_2, \ldots, S_N \). The channel \( C_i \) periodically broadcasts segments \( S_j \), where \( j = 2^{i-1}, \ldots, 2^i - 1 \). A group of consecutive \( 2^{i-1} \) data segments will be mentioned as a “cycle” of \( C_i \) in the rest of the paper.

The storage requirement for buffering varies by the starting time to receive the video. In the best case, the video segments are directly played out just after they have been received and therefore no buffer is required. However, the buffer required is about \( L/2 \) in the worse case. The maximum service delay (i.e. the maximum waiting time for a client, denoted as \( d \)) is \( L/(2^k - 1) \).
2.2 The seamless channel transition (SCT) scheme

The SCT scheme [8] is the first and the only channel transition scheme up to now with the seamless property. The basic idea of SCT is to build a multiple relationship among segment lengths with different channel assignments. In Fig. 1(a), the segment lengths are $L/3$, $L/7$ and $L/15$ if the numbers of allocated channels are 2, 3 and 4, respectively with typical FB design. With the “data padding” technique, a dummy video stream is added to the original video. The size of the dummy video $|V_{\text{dummy}}|$ is decided as $L/(2^\alpha - 1)$, where the factor $\alpha$ is the minimum number of allocated channels for a video. After padding, the new video $V'$ can be divided into $2^k$ equal segments, $k \geq \alpha$. In Fig. 1(b), $\alpha = 2$ and a dummy video of length $L/3$ was appended to the original video. The new video streaming $V'$ of length $4L/3$ is divided into 4, 8 and 16 segments, respectively.

Fig. 2 demonstrates the segment arrangements for $k=2$, 3 and 4 in SCT.

3. The Proposed Channel Transition Scheme

Our proposed channel transition scheme includes two procedures for the positive channel transition (increasing allocated channels) and negative channel transition (decreasing allocated channels). The description and analysis are given as below.

3.1 Negative channel transition

Suppose $m$ is the number of channels to be released. We denote the remaining $k-m$ channels be $C_j'$, $1 \leq j \leq k-m$, and each $C_j'$ starts with the new segment $S_j'$, $u=2^j$, as the first segment after transition. Here we let $C_1'$ coincide with $C_1+m$, $1 \leq j \leq k-m$.

When the request of negative channel transition is granted at $T_a$, we proceed to broadcast $2^{i-1}$ segments as the last cycle in channel $C_i$. So that the clients issued requests earlier than $T_a$ will pick up their remaining data completely. All the video requests later than $T_a$ are now served by new channel assignments in accordance with new video segmentation.

We let $C_1'$ activate immediately following the ending of $C_{m+1}$. The starting time of $C_j'$, $2 \leq j \leq k-m$, is $(2^{j-1} \cdot d')$ later than the starting time of $C_j'$, in accordance with the definition of FB. In Fig. 3, $m=1$ and the ending time of $C_2$ is $T_a$. The starting times of $C_1'$, $C_2'$, and $C_3'$, are $T_a$, $T_a+d'$, and $T_a+2d'$, respectively.
and $T_a + 3d'$ respectively. Now we must prove that there exists no overlap between the placement of old and new segments. That is, the ending time of $C_{j,m}$ always expires before the starting time of $C_{j}'$. Let the lengths of the old and new segments be $d$ and $d'$ respectively. According to the definition,

$$d = L/(2^j-1) \text{ and } d' = L/(2^{k,m}-1),$$

$$d'/d = (2^k-1)/(2^{k,m}-1).$$

The ending time of $C_{j,m}$ is $(2^{j,m}-1)2^m d$ later than the ending time of $C_{m+1}$, where the ending time of $C_{m+1}$ is also the starting time of $C_{j}'$. We have,

$$\frac{(2^{j-1}-1)d}{(2^{j,m}-1)}d' = d'(2^{j-1}-1)/(2^{k,m}-1) - d'(2^{j,m}-2^m) = d'(2-1)(2^{m-1})/(2^{k,m}-1) > 0,$$

given that $m < k$, $j$, $k$ and $m$ are positive integers. The result indicates that $C_{j,m}$ always ends before the starting time of $C_{j}'$. Note that the difference between the starting time of the last segment in $C_j$ (i.e. $T_a$) and the starting time of $C_{j}'$ (i.e. $T_b$) is $2^md$, which is smaller than $d'$. In Fig. 3, the length of period $(T_a, T_b)$ is $2L/15$, which is smaller than $d' (L/7)$.

### 3.2. Positive channel transition

The process of positive channel transition is similar to the negative channel transition, unless $S_i'$ starts at $T_a + d$ in $C_{j}'$; hence the introduction is omitted here. Fig. 4 illustrates an example with the number $m$ of added channels as one. We can easily prove that there exists no overlap between the placement of old and new segments. The time difference between $T_a$ and $T_b$ is $d$.

The buffer required for performing our channel transition scheme will not exceed the maximum buffer requirement in the original FB scheme. For the space limitation of the paper, we do not explain the analysis of buffer requirement here. Both of our proposed negative and positive channel transition schemes are seamless since all video segments will arrive at their respective clients in time, and the service delay for a request is restricted by the larger one between $d$ and $d'$ during the channel transition.

### 4. The Comparison and Simulation Results

The comparison between the SCT scheme in [8] and our proposed one are given in this section. We concern three issues including: bandwidth waste, increase of average waiting time and buffering space requirement.

#### 4.1 Bandwidth waste

The SCT scheme in [8] uses the data padding technique that a suitable size of dummy video stream is added to the original video. Since the dummy segments have to broadcast periodically, this causes regular bandwidth waste. In [8], the total amount of bandwidth waste is bounded by $L/(2^j-1)$, that is, the waste ratio decreases as the number of available channels increases, where $\alpha$ is the minimum number of allocated channels mentioned in Section 2. For example, the length of dummy video is $L/3$ if $\alpha = 2$. If four channels are currently allocated, $S_{13} - S_{15}$ in $C_4$ are dummy segments and the waste ratio is about 0.094. If six channels are allocated, $S_{67} - S_{69}$ in $C_6$ are dummy segments and the waste ratio decreases to 0.078.

The bandwidth waste in our proposed scheme only occurs during the channel transition as shown in Fig. 3 and Fig. 4. This bandwidth waste, $w$, in the negative case is

$$w = \sum_{j=2}^{\alpha-2} \frac{d(2^j-1)(2^{m+1})}{(2^{k,m}-1)} = \sum_{j=2}^{\alpha-2} \frac{L(2^j-1)(2^{m+1})}{(2^{k,m}-1)},$$

and in the positive case is

$$w = \sum_{j=2}^{\alpha} \frac{d(2^j-2^i-1)(2^{m+1})}{(2^{k,m}-1)} = \sum_{j=2}^{\alpha} \frac{L(2^j-2^i-1)(2^{m+1})}{(2^{k,m}-1)},$$

![Fig. 5. The relationship between the waste bandwidth and the original channel assignment $k$ in negative channel transition.](image)

![Fig. 6. The relationship between the waste bandwidth and the original channel assignment $k$ in positive channel transition.](image)
Table 1. The comparison of bandwidth waste statuses between our proposed scheme and the SCT scheme.

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Proposed</th>
<th>SCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(min)</td>
<td>0~30</td>
<td>30~60</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>Total</td>
</tr>
<tr>
<td>Allocated</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Channels</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Throughput</td>
<td>180</td>
<td>120</td>
</tr>
<tr>
<td>(min)</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>0</td>
<td>2.38</td>
</tr>
<tr>
<td>Waste (min)</td>
<td></td>
<td>14.06</td>
</tr>
<tr>
<td>Waste Ratio</td>
<td>0</td>
<td>0.020</td>
</tr>
</tbody>
</table>

Table 2. The comparison of buffering space requirement between our proposed scheme and the SCT scheme [8].

<table>
<thead>
<tr>
<th>k</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>FB /Proposed</td>
<td>40.00</td>
<td>51.42</td>
<td>56.00</td>
<td>58.06</td>
<td>59.04</td>
<td>59.52</td>
<td>59.76</td>
<td>59.88</td>
</tr>
<tr>
<td>SCT, α=2</td>
<td>60.00</td>
<td>70.00</td>
<td>75.00</td>
<td>77.5</td>
<td>78.75</td>
<td>79.37</td>
<td>79.68</td>
<td>79.84</td>
</tr>
<tr>
<td>SCT, α=3</td>
<td>n/a</td>
<td>60.67</td>
<td>65.32</td>
<td>67.69</td>
<td>68.82</td>
<td>69.41</td>
<td>69.70</td>
<td>69.85</td>
</tr>
<tr>
<td>SCT, α=4</td>
<td>n/a</td>
<td>n/a</td>
<td>60.48</td>
<td>62.73</td>
<td>63.86</td>
<td>64.43</td>
<td>64.71</td>
<td>64.85</td>
</tr>
<tr>
<td>SCT, α=5</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>60.27</td>
<td>61.38</td>
<td>61.94</td>
<td>62.32</td>
<td>62.36</td>
</tr>
</tbody>
</table>

where \(d\), \(k\), and \(L\) were defined in Section 3.1 and Section 3.2. Fig. 5 and Fig. 6 illustrate the relationships between \(w\) and \(k\) in both negative and positive cases. We measure these values in unit of \(L\), the length of the video. For example, in the case of six channels being used and two channels being released then, the bandwidth waste is \(0.079L\) for the channel transition. If channel transitions are not performed very frequently, the bandwidth waste ratio will approach to zero.

An instance to compare these two schemes is given as follows. For a 30-min video, we observed the broadcasting for an hour, and the number of allocated channels decreased from six to four at the half of this hour. The bandwidth waste statuses for these two schemes are illustrated in Table 1 (\(α = 2\) for the seamless channel transition).

4.2 Increase of average waiting time

In SCT scheme, a suitable size of dummy video is added to the original video, and thus, increases the size of each segment. Therefore, the service delay for each client will be longer. In our proposed scheme, we do not change the segment lengths with their respective numbers of allocated channels in FB. The service delay during the transition period is either \(d\) or a number smaller than \(d\). Therefore no extra waiting time is yielded.

4.3 Buffering space requirement

As mentioned, by the increasing of sizes of all segments, a larger buffering space to the client is required in the SCT scheme [8]. Table 2 reveals the buffering space required by the original fast broadcasting scheme and the seamless channel transition scheme (negative channel transition from \(k+1\) to \(k\)) for a 120-min video. Note that the buffering space requirement of ours equals to the original fast broadcasting scheme.

5. Conclusion

In this paper, we propose a new channel transition scheme over FB scheme. In comparison to the existing SCT scheme, our scheme causes smaller bandwidth waste. The client waiting time and buffering space requirement are kept the same with the performances in FB scheme, and therefore smaller than those in SCT scheme. Unlike SCT that is dedicated for FB scheme, the concept of our proposed channel transition scheme is more extensive. We have analyzed the feasibility of channel transitions in harmonic and skyscraper broadcasting. Our future work is to adapt our proposed channel transition technique for these broadcasting schemes.

6. References