A SCHEDULED BROADCASTING PROTOCOL FOR EFFICIENT VIDEO ON DEMAND

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ABSTRACT

Broadcasting protocols can improve the efficiency of video on demand services by distributing videos that are likely to be simultaneously viewed by many clients. In this work we have developed an efficient video broadcasting protocol called the scheduled broadcasting protocol. This protocol reduces the complexity managing incoming streams as well as the bandwidth required to broadcast. To assess the benefit of the new protocol, we perform various simulations to compare its performance with that of previous broadcasting protocols. With simulation results, we show that our protocol's required bandwidth is very close to the theoretical minimum for all client waiting times. Furthermore, comparison with previous broadcasting protocols, shows how our broadcasting protocol can dramatically reduce both the number of simultaneous streams during the video duration and that of required modules for watching a video.

1. INTRODUCTION

Broadcasting protocol for video on demand is important for many multimedia applications such as video entertainment and distance lecture. Broadcasting protocols can provide video-on-demand service with a small amount of fixed-waiting time. Instead of responding to each client requests, the broadcasting protocol saves server bandwidth by periodically broadcasting the various segments of popular videos according to a schedule.

The broadcasting protocol has several important performance indices such as required bandwidth, stream decoding complexity, and storage requirement. The first efficient broadcasting protocol, Phyrmid broadcasting, was indroduced by Viswanathan and Imielinski[3]. Phyramid bradcasting technique required a big client buffer space storing up to 70% of the length of video[2]. Juhn and Tseng's harmonic broadcasting protocol[1] supported a 120-minute movie every 10 minutes, requiring only 3.2 video channels. Paris compared his pagoda broadcasting protocol[4] to other broadcasting protocols with respect to required bandwidth and managing stream complexity. In this work we present a better broadcasting protocol that requires less bandwidth and offers decreased stream decoding complexity. The rest of the paper is structured as follows. Section 2 reviews relevant video broadcasting protocols and describes properties behind existing broadcasting protocol. Section 3 presents the scheduled broadcasting protocol, and introduces its theoretical backgrounds and the basic protocol algorithm. Also presented are the simulation results and discussion of practical aspects concerning the required bandwidth and the decoding complexity of other video broadcasting protocols. Finally, we give our concluding remarks in Section 4.

2. PREVIOUS WORK

Even though harmonic broadcasting[1] achieves the lowest bandwidth cost about a given access time, the protocol can't guarantee actual on-time delivery of all frames. Thus, some variants of the harmonic broadcasting protocol have been developed. Quasi-harmonic broadcasting(QHB) is one variant. The QHB divides each video into N equal segments and broadcasts the first segment repeatedly on the first channel. But other segments i, for $2 \leq i \leq N$, are divided into $im - 1$ fragments for parameter m, and the client will receive m fragments from each channel per time slot. The total required bandwidth is $B_{QHB} = b + \sum_{i=2}^{N} \frac{bm}{im-1}$, where b is the video consumption rate. But, the quasi-harmonic broadcasting protocol is difficult to implement for small client waiting time because of the high decoding complexity.

Another variant of the harmonic broadcasting protocol, the polyharmonic broadcasting protocol(PHB) reduces the required bandwidth about a given access time by using a small fixed waiting delay. The PHB breaks a video into equal N segments of equal duration d. The total required bandwidth by the PHB is given by $B_{PHB} = \sum_{i=1}^{N} \frac{b}{m+i-1}$. However, polyharmonic broadcasting requires m times more segments than the harmonic broadcasting protocol to achieve the same maximum waiting time.

The pagoda protocol[4] described the simultaneous incoming stream management complexity as well as the required bandwidth for video broadcasting. The pagoda protocol also partitions a video into N fixed-size segments of

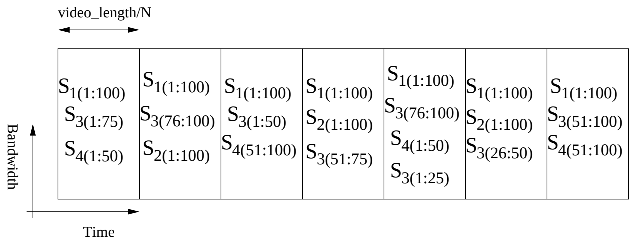

Fig. 1. An example of the first seven time slots of the scheduled broadcasting protocol when $N = 4$, $md = 1$, and $K = 100$

duration d, where $d(= \frac{video\_length}{N})$ is also defined as a time slot. Unlike harmonic protocols, the pagoda protocol broadcasts these segments at the fixed bandwidth having multiples of the consumption rate but at different periodicities. The bandwidth of the pagoda protocol B_{PAGODA} depends on the total number of segments being broadcast. $N(n) = \{^{4(5^{k-1})-l, n=2k}_{2(5^k)-1, n=2k+1}$, where $B_{PAGODA} = nb$ and b is the video consumption rate.

Like the delayed broadcasting protocol, the fixed-delay pagoda broadcasting protocol(FDPB)[5] requires all clients wanting to watch a video to wait for a fixed time interval $w = md$, where m is some integer $1 \leq m$. The fixed-delay pagoda broadcasting protocol divides each video into N equal-size segments of duration $d = D/N$ and broadcasts over k channels C_i with $1 \leq i \leq k$, where D is the duration of the video and C_i was approximately partitioned into $\sqrt{m+i-1}$ subchannels. Like the pagoda protocol, these N segments are broadcast at different frequencies over the k channels, each segment transmission occupying a slot of duration d.

3. SCHEDULED BROADCASTING PROTOCOL

We propose the scheduled broadcasting protocol(SBP) as a video broadcasting protocol, which can deliver video data on time with low bandwidth requirement and low decoding complexity. Unlike previous broadcasting protocols, the new protocol assumes that the set-top-box will receive data through a shared communication stream on which the various segments of video are broadcast. It is assumed that the set-top box has adequate storage space to buffer incoming video segments from the communication stream. The new protocol defines a module as a broadcasting data unit of each segment for every slot. Unlike other video broadcasting protocols, the SBP doesn't use pre-defined isolated stream channels, which are used in previous harmonic and pagoda broadcasting protocols. Rather, the sequence inside stream modules of the scheduled broadcasting protocol is identical with that of other broadcasting protocol streams. The new approach requires some schemes to divide receiving data from the shared communication stream into some stream modules every slot. And, like other delayed broadcasting protocols, the scheduled broadcasting protocol requires that segment S_i will not be consumed until $md + i - 1$ slots have elapsed from the time the client started storing data from the video server. Clients may receive stream modules in any arbitrary order like other video broadcasting protocols.

The Scheduled Broadcasting Protocol Bandwidth Bounds	
LBW	$\lceil K * \sum_{i=1}^{N} \frac{1}{(i+md-1)} \rceil * \frac{b}{K}$
UBW	$\lceil K * (1 + \sum_{i=1}^{N-1} \frac{1}{(i+md-1)}) \rceil * \frac{b}{K}$

Table 1. Lower and Upper Bandwidth Bounds

The SBP is different from previous broadcasting protocols in two aspects. First, the SBP allows all segments to share the communication stream using a variable module size to broadcast videos increasing the bandwidth utilization of broadcasting video. This makes for lower bandwidth requirements than other pagoda broadcasting protocols. Second, previous broadcasting protocols use pre-defined static numbers of simultaneous streams during video broadcasting, while the SBP uses variable numbers of simultaneous streams every slot.

The SBP divides a video into N equal segments. The size of the video is $S = L * b$, where L is the duration of the video and b is the consumption rate of the video. One aspect that differs from previous schemes is that the SBP subdivides each segment up to K modules, where K is some multiple integer of 100. The SBP defines a module M_i as a broadcasting data unit of each segment where $1 \leq i \leq K$. The SBP uses $\frac{b}{K}$ and $\frac{S}{N*K}$ as basic units of bandwidth calculation and broadcasting module size computation. The whole video S can be represented as follows.
$S = \sum_{h=1}^{N} S_h$, $S_h = \sum_{i=1}^{J} M_i^h$, where J is some integer $1 \leq J \leq K$.
Unlike pagoda broadcasting protocols, the SBP can divide a segment into some modules having different sizes. To maintain segment data consistency, the SBP simultaneously broadcasts all modules every slot through a single communication stream having a rate that is a multiple of the consumption rate. Like fixed delay broadcasting protocols, the SBP uses maximum waiting slot parameter md which is some integer $1 \leq md$. Thus, the SBP requires all clients wanting to watch a video to wait until md waiting slots have elapsed.

The SBP delivers each segment with different transmission rates for efficient video broadcast. If N segments with md waiting slots to watch a video are broadcast, the scheduled broadcasting protocol needs $N + md - 1$ slots to broadcast all N segments. The first segment S_1 requires at least $\frac{N+md-1}{1+md-1}$ time transmissions,

Initialization:

decide segment size for video broadcasting
decide a module unit about the segment
assign broadcasting periods to all segments
decide the required bandwidth of the SBP

Basic Algorithm:

for i:= 1 to N **do**
  for k:= K to 1 **do**
    select a S_i's module for bandwidth slot allocation
    if valid module and bandwidth available **then**
      for j := M_k^i's next_period_slot **to** M_k^i's previous_slot **do**
        select a bandwidth slot for broadcasting M_k^i
      end for loop
      if M_k^i was successfully allocated **then**
        update M_k^i's allocation information
        update S_i's modules allocation information
      end if
    end if
  end for loop
end for loop

Fig. 2. The Scheduled Broadcasting Protocol

the second segment S_2 requires at least $\frac{N+md-1}{2+md-1}$ time transmissions, and the last segment S_N requires at least $\frac{N+md-1}{N+md-1}$ time transmission. If we assume that all modules M_i^h, $1 \leq i \leq h + md - 1$, of segment S_h have the same module size, we extract the lower bandwidth bounds of the scheduled broadcast protocol(LBW) as follows, $LBW_{SCHEDB} = \lceil K * \sum_{i=1}^{N} \frac{1}{(i+md-1)} \rceil * \frac{b}{K}$.
Since the scheduled broadcasting protocol follows High Frequency Segment First Priority policy when the protocol broadcasts segments over the communication stream, the SBP requires a little more bandwidth than when all segments are equally distributed. In Table 1, we have displayed the lower bandwidth boundary(LBW) and the upper bandwidth boundary(UBW) to find the minimum required bandwidth of the SBP. The UBW in Table 1 was extracted by using some worst case bandwidth use of the SBP.

Figure 2 represents the basic algorithm of the scheduled broadcasting protocol. The SBP finds minimum required bandwidth with a trial and error method, starting from the LBW. The SBP always finds the minimum required bandwidth for broadcasting segments before reaching to its UBW. As shown in Figure 2, the SBP traces on-time delivery conditions about all segments by a module unit. If M_i^h, $1 \leq i \leq K$, broadcasts at t_0 slot, this module should broadcast the next time by $md + h + t_0 - 1$ slot. The module size of each segment is decided after bandwidth allocation is

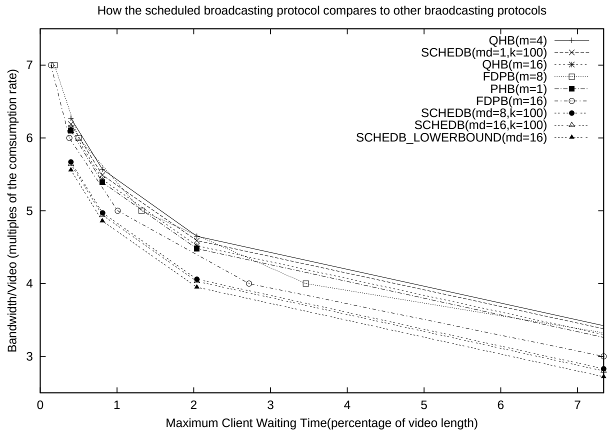

Fig. 3. Bandwidth comparison achieved by various protocols about different maximum waiting times

finished. The number of modules depends on the bandwidth availability within the module's period slots. Generally, the more bandwidth the SBP can get, the fewer modules the SBP will broadcast.

Figure 3 displays the bandwidth needed by the SBP and other video broadcasting protocols to guarantee a given waiting time. As in Figure 3, the maximum client waiting times on the x-axis are expressed as percentages of the video duration. The required bandwidth on the y-axis represents multiples of the video consumption rate. As one can see, the bandwidth required by the SBP is significantly lower than that required by other broadcasting protocols as md increases slightly. The graph also indicates that the SBP with $md = 8$ requires lower bandwidth than that of fixed-delay pagoda protocol with bigger maximum waiting slots $m = 16$. The figure further shows that the SBP with $md = 16$ and $k = 100$ provides the required bandwidth that is very close to its lower bandwidth bounds(LBW) throughout x-axis.

Figure 4 presents maximum simultaneous streams during the video duration achieved by video broadcasting protocols. The numbers on the x-axis display the maximum client waiting times as percentages of the video duration, all quantities on the y-axis represent the maximum number of simultaneous streams during the video duration. As some papers previously described, the decoding of incoming video streams is an important issue in video on demand because managing a large number of independent data streams is a difficult task[4]. Since the SBP doesn't use predefined isolated stream structure, the protocol needs some scheme to partition the incoming data from a single communication stream into some stream modules for every slot. As one can see, for instances where $waiting\ time \leq 4\%$ the SBP dramatically reduces the number of simultaneous streams compared to other video broadcasting protocols.

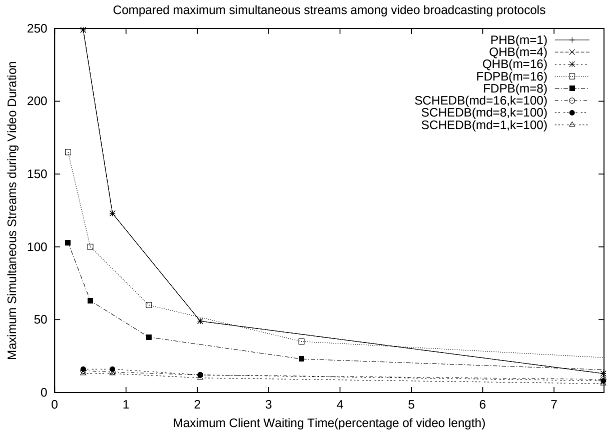

Fig. 4. Compared maximum simultaneous streams during the video duration of broadcasting protocols versus maximum client waiting times

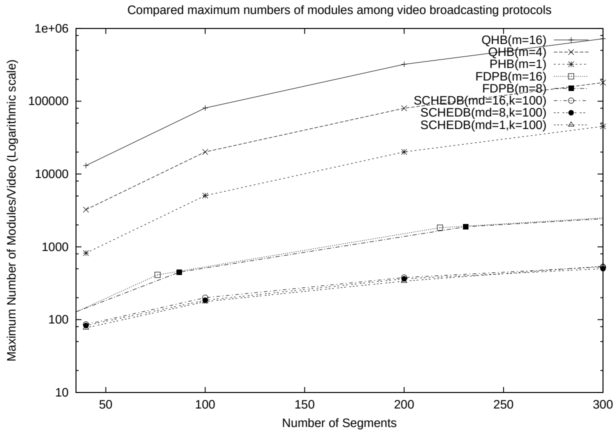

Fig. 5. Compared maximum client receiving modules versus the numbers of segments

The scheduled broadcasting protocol allocates segments exclusively over the given communication stream by high frequency segment first. The harmonic broadcasting protocol broadcasts all segments every slot and previous pagoda broadcasting protocols calculate the number of required simultaneous streams according to the number of segments. This means that other broadcasting protocols need more simultaneous streams for video broadcasting as the number of segments increases. The SBP broadcasts exclusive segments in each slot being minimally affected by increasing the number of segments. The graph further indicates that increasing md in the scheduled broadcasting protocol doesn't display significant difference in the number of simultaneous streams compared with that of $md = 1$.

Figure 5 displays the maximum numbers of modules for watching one video through different numbers of segments. Like the number of simultaneous streams, as broadcasting modules increase during a given video duration, the decoding complexity for on-time display will increase. The numbers of segments on the x-axis are expressed and the maximum numbers of modules during the video duration on the y-axis are represented with the logarithmic scale. As shown in Figure 5, the SBP significantly reduces receiving stream modules by using the variable module size scheme.

4. CONCLUSION

Broadcasting protocols can improve the efficiency of video on demand services by distributing videos that are likely to be simultaneously viewed by many clients. In this work we have developed an efficient video broadcasting protocol, the scheduled broadcasting protocol, that reduces the managing incoming stream complexity as well as the bandwidth required to broadcast by using new schemes. We have performed simulation of the SBP and other broadcasting protocols and compared performance indices: required bandwidth, stream decoding complexity, and storage requirement. The required bandwidth by the SBP is significantly lower than that required by previous broadcasting protocols and its required bandwidth is very close to the theoretical minimum about all waiting times. The SBP dramatically reduces the numbers of simultaneous streams, especially in the low waiting time scope, during the video duration. It also reduces the numbers of required modules for watching a video at these times. Moreover, we found that the SBP leads to storage requirements below 45 percent of the video size about reasonable numbers of segments.

5. REFERENCES

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