VBR Video Retrieval

By H.L. Lai
Outline

- Introduction
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- Multiplexing Streams
- E-EDF Scheduling
- Simulation Results
- Problems
Introduction


- Maximum bit rate of VBR videos can be several times that of the minimum in the same video clip.
- Without proper buffering and scheduling, the required bit rate would be the maximum bit rate, which is inefficient.
Single Stream Case

Transmitted

required amount for playback
Single Stream Case

Diagram showing the relationship between buffer size, amount of data, and time. The graph illustrates steps and changes in data size over time, with annotations for concave and convex change points.
Single Stream Case

- Peak data rate can be reduced by buffering.

- Max. bit rate = \[ \max_{0 \leq a < b \leq N} \frac{L(b) - U(a)}{b - a} \]

- Min. bit rate = \[ \min_{0 \leq a < b \leq N} \frac{L(b) - L(a)}{b - a} \]
Multiplexing Streams

- Consider the multiplexing of $K$ streams, each with feasible regions bounded by $(L_i, U_i)$.
- Feasible region of multiplexed stream is:
  \[
  \left( \sum_{i=1}^{K} L_i, \sum_{i=1}^{K} U_i \right)
  \]
- If $S_i$ is a valid schedule of stream $s_i$, then $\sum_{i=1}^{K} S_i$ is a valid schedule of the multiplexed stream $\sum_{i=1}^{K} s_i$. 
Multiplicitying Streams

Inevitable Bandwidth:

$$\max_{0 \leq a < b \leq N} \sum_{i=1}^{K} \frac{L_i(b) - U_i(a)}{b - a}$$
E-EDF Scheduling

- Eligible Earliest Deadline First (E-EDF) scheduling scheme is to order tasks in the way that the task which is eligible and has the earliest deadline is handled first.

- Eligible means that the transmission of that video block does not lead to buffer overflow.
E-EDF Scheduling

- Algorithm: at any time, select and transmit the eligible block with the earliest deadline.

- Claim: an E-EDF schedule under the inevitable bandwidth does not lead to data starvation.
E-EDF Scheduling

- Proof: (by contradiction)
  - Suppose starvation occurs at time $t(j)$, and $t(i)$ is the last time before $t(j)$ that either a block with deadline later than $t(j)$ is transmitted, or nothing is transmitted.
  - Call streams with deadlines between $t(i)$ and $t(j)$ “pending streams”
  - Then from the time $t(i)$ to $t(j)$, we should be transmitting the pending streams at the inevitable bandwidth.
E-EDF Scheduling

Proof: (cont.)

- At time $t(i)$, all pending streams should have their buffers filled $S_k(t(i)) = U_k(t(i)), k \in \text{pending}$
- Starvation occurs at $t(j)$ which means data transmitted between $t(i)$ and $t(j)$ is smaller than $
\sum_{k \in \text{pending}} L_k(t(j)) - S_k(t(i))$
- For every non-pending stream:
  $L_k(t(j)) - S_k(t(i)) \leq 0, k \not\in \text{pending}$
E-EADF Scheduling

Proof: (cont.)

- Sum up all streams, the data transmitted between \( t(i) \) and \( t(j) \) is less than:

\[
\sum_{k=1}^{K} (L_k(t(j)) - S_k(t(i)))
\]

- Contradicts to the earlier result that we should be transmitting at the inevitable bandwidth:

\[
\max_{0 \leq t(i) < t(j) \leq N} \sum_{i=1}^{K} \frac{L_i(t(j)) - U_i(t(i))}{t(j) - t(i)}
\]
Simulation Results

<table>
<thead>
<tr>
<th>Video Name</th>
<th>Avg. Rate (Mbps)</th>
<th>Frame Sizes (Bytes)</th>
<th></th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Avg</td>
<td>Max</td>
<td>Min</td>
<td>S. Dev.</td>
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<tr>
<td>Beauty and Beast</td>
<td>3.04</td>
<td>12661</td>
<td>30367</td>
<td>2701</td>
<td>3580</td>
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<tr>
<td>Big</td>
<td>2.96</td>
<td>12346</td>
<td>23485</td>
<td>1503</td>
<td>2366</td>
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<td>Crocodile Dundee</td>
<td>2.59</td>
<td>10773</td>
<td>19439</td>
<td>1263</td>
<td>2336</td>
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<td>E.T.</td>
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<td>9022</td>
<td>19961</td>
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<td>Home Alone 2</td>
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<td>22009</td>
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<td>13836</td>
<td>23291</td>
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<td>3183</td>
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<td>11363</td>
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<td>Junior</td>
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<td>Rookie of the Year</td>
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<td>27877</td>
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<tr>
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<td>1457</td>
<td>2608</td>
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<tr>
<td>Sleepless in Seattle</td>
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<td>9477</td>
<td>16617</td>
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<td>Speed</td>
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<td>Total Recall</td>
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<td>11978</td>
<td>24769</td>
<td>2741</td>
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Video Clips Used
Simulation Results

(a) 10-200 streams, 1MB buffer

(b) 100 streams, 50KB-10MB buffer
Simulation Results

(a) 100KB and 10MB buffer

(b) 100KB, 1MB and 10MB buffer
Simulation Results

(a) 10-200 streams, 1MB buffer

(b) 100 streams, 50KB-10MB buffer
Problems

- The bandwidth limit of an individual stream is not considered.

- Solution: Pre-Play Buffering
Problems

Transmit at Max. bandwidth

initial buffer size
Problems

- Bad worse case bandwidth requirement of multiplexed stream.

- Solution: Schedule to avoid the high bit rate portions of streams to be sent at the same time.
Problems

Stream A

<table>
<thead>
<tr>
<th>A_i</th>
<th>A_{i+1}</th>
<th>A_{i+2}</th>
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</table>

Stream B

<table>
<thead>
<tr>
<th>B_i</th>
<th>B_{i+1}</th>
<th>B_{i+2}</th>
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Stream C

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<thead>
<tr>
<th>C_i</th>
<th>C_{i+1}</th>
<th>C_{i+2}</th>
<th>...</th>
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</table>

Sum

<table>
<thead>
<tr>
<th>S_i</th>
<th>S_{i+1}</th>
<th>S_{i+2}</th>
<th>...</th>
</tr>
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</table>

not feasible!