Background

- Growth of computing power
- Proliferation of the Internet
- Distributed multimedia applications

Increasing of video streaming services over the Internet

High-quality and low-delay video streaming service is required
Technique for low-delay data delivery

- Proxy mechanisms
  - Widely used in WWW systems
  - Reduce network load

Applying to the video transfer

Problems
- A current proxy system only handles files whereas a single video stream is very large
- Client requests on the video quality considerably differ due to heterogeneity in the available bandwidth

  - Segmentation of video data
  - Video quality adjustment in the proxy
Research Targets

• Proposal of proxy caching mechanisms with video quality adjustment
  – Low-delay video streaming service while meeting user’s demand
    • Data retrieval with consideration on client’s request
    • Prefetching data that clients are going to require in the future
  – Reduce required cache buffer size
    • Segmentation of video data for retrieval, caching and forwarding
    • Replacement of cached data with consideration of size, quality and re-usability of data
Video streaming system using proxy cache with video quality adjustment

Server

Request (high quality)

Proxy

Cache Buffer

Forward (high quality)

Request (high quality)

Forward (high quality)

Read (low quality)

Read (low quality)

MPEG-2 Video Stream

Client 1

high quality

Request (low quality)

Forward (high quality)

Forward (low quality)

low quality

Client 2
Assumptions on our proposed mechanisms

- MPEG-2 video
- Unit of data for retrieval, caching and forwarding
  - GoP (Group of Pictures)
- A client periodically requests the proxy to send a GoP with user’s demand
- Rate control for sending video data
  - TFRC (TCP Friendly Rate Control)
- Available Bandwidth
- Quality adjustment is performed by re-quantization filter

![Graph showing relationship between average rate, quantizer scale, and video quality]

- Video quality
- Reciprocal of a quantizer scale
- TFRC rate
- Average rate [Mbps]
Data retrieval

• Cache hit
  – The proxy adjusts cached GoP to the request and transmits it to the client

• Cache miss
  – Server-Proxy bandwidth is sufficient
    • Data retrieval with consideration on current and future demands
  – Server-Proxy bandwidth is insufficient
    • Data retrieval with consideration on trade-off between quality and delay
Data retrieval
- Sufficient bandwidth -

• Considering clients that are going to require the GoP in the future, the proxy retrieves the GoP of maximum quality among their demands.
Data retrieval

- Insufficient bandwidth -

- Trade-off between quality and delay

Which does the user give priority to, quality or timeliness?

Introducing a parameter $\beta$

$\beta$ is defined as the ratio of the acceptable quality to the demand
Data retrieval  
- Insufficient bandwidth -

- Control based on $\beta$

<table>
<thead>
<tr>
<th>Quality of cached GoP</th>
<th>Quality of the client’s request</th>
<th>$\geq \beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>No</td>
<td>The proxy sends the cached GoP</td>
<td>Yes</td>
</tr>
<tr>
<td>Quality of the GoP which the proxy can retrieve from the server</td>
<td>Quality of the client’s request</td>
<td>$\geq \beta$</td>
</tr>
<tr>
<td>Yes</td>
<td>The proxy retrieves the GoP from the server</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Quality of the GoP which the proxy can provide</td>
<td>$&lt; \beta$</td>
</tr>
<tr>
<td>Quality of the client’s request</td>
<td>The proxy retrieves the GoP of the acceptable quality from the server</td>
<td></td>
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</tbody>
</table>
Prefetching mechanism

- Range of examination for prefetching (prefetching window)
- Requested GoP
- Candidate GoP for prefetching
- Requested quality
- Quality of the cached data

Position in the video stream

Requested GoP
Replacement Algorithm

1. Choose a candidate GoP for replacement
2. Try the quality adjustment to decrease the size of the candidate
3. Eject the candidate from the cache

Requested GoP by a client
GoP in the prefetching window
No priority
Candidate GoP for replacement
Simulation model

- Video stream is two hours long
- 10 clients watch the same video stream from the beginning to the end without interactions
- The inter-arrival time between two successive client participations follows the exponential distribution whose average is 1,800 seconds
Evaluation criteria

• Required cache buffer size
  – Amount of cached data

• Playout delay
  – Maximum jitter

• Degree of satisfaction on delivered video
  – The average ratio of the delivered video quality to the demand
Simulation result

- Amount of cached data -

- Traditional method (infinite cache, no quality adjustment)

- Proposed mechanism (infinite cache, no prefetching, $\beta = 1$)

- Proposed mechanism (20 Gbits cache, prefetching, $\beta = 0.6$)
Simulation result

- Playout delay -

- Traditional method (infinite cache, no quality adjustment)
- Proposed mechanism (infinite cache, no prefetching, $\beta = 1$)
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Simulation result
- Degree of satisfaction on delivered video -

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Conclusion

• Conclusions
  – We proposed proxy caching mechanisms with video quality adjustment
  – Simulation results show that our system can accomplish a low-delay video streaming service while meeting user’s demand and available bandwidth

• Future works
  – Reducing playout delay
  – Considering interactions such as rewinding, pausing and fast-forwarding