Cache Replacement Algorithm for P2P Media Streaming

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Backgrounds
- client-server model -

High transfer delay

Diverse user demands

Backgrounds
- P2P (Peer-to-Peer) architecture -

P2P is a network paradigm to solve those problems.

Proposed Media Streaming on Pure P2P Networks
Previous Work
scalable and continuous media streaming on pure P2P networks -

We proposed efficient mechanisms for scalable and continuous media streaming [1]
  - Segmentation of media stream
  - For efficient use of network bandwidth and cache buffer
  - Scalable block-search method
  - Per group search
  - Provider peer determination algorithm
  - To achieve continuous media playout


Problem Found in Our Previous Work
If LRU (Least Recently Used) is used as a cache replacement algorithm
- Popular media streams are excessively cached in the network
- Unpopular media streams disappear from the network

Solution
Bio-inspired cache replacement algorithm considering balance between supply and demand for media streams in the network
- Estimation of supply and demand per media stream
- Determination of an appropriate media stream to be replaced

Estimation of Supply and Demand (Overview)
Estimate supply and demand based on locally available information
- Supply
  - Response message
- Demand
  - Query message

Estimation of Supply and Demand (Overview)
Estimate supply and demand based on locally available information
- Supply
  - Response message
  - Relayed response message
- Demand
  - Query message
  - Relayed query message

Every peer estimates supply and demand per media stream by itself
Determination of Appropriate Media Stream to be Replaced

Our proposed media streaming is a distributed system. In biology, insects, such as ants, also construct a highly structured organization only through indirect communications among individuals. Recently, a proposed model of division of labor in a colony of wasps can be transformed into a decentralized adaptive algorithm of task allocation [2].


Division of Labor and Task Allocation

Original model is division of labor in a colony of social insects. There are a lot of individuals and several types of tasks in a colony. It is preferred that the number of individuals that perform a task follows the demand to the task.

Probability $P_i$ that individual $j$ performs task $i$: $P_i = \frac{s^2 (j,i) + \theta_j}{\theta_j + \theta_i}$

- As a media excessively exists, it tends to be discarded.
- Supply and demand for media streams will be well-balanced.

Bio-inspired Cache Replacement Algorithm Based on Division of Labor and Task Allocation

Original division of labor and task allocation $P_j = \frac{s_i}{s^2 (j,i) + \theta_j}$

Proposed cache replacement algorithm $P_j (j,i) = \frac{s^2 (j,i) + \theta_j}{\theta_j + \theta_i}$

- Step1: Estimation of Supply and Demand -
  - The estimation is performed per round.
  - Peer $j$ estimates supply $S(j,i)$ and demand $D(j,i)$ for media stream $i$.
    - Response messages including search results.
    - Query messages.

Bio-inspired Cache Replacement Algorithm - Step2: Determination of Media Stream for Replacement -

Based on the "division of labor and task allocation" Probability of replacement of media stream $i$: $P_i (j,i) = \frac{s^2 (j,i) + \theta_j}{\theta_j + \theta_i}$

- Step3: Replacement of Candidate Media Stream -
  - Discard media stream $i$ in a block-by-block basis from the head or tail of the media stream at random.
  - Regulate the response threshold as follows.

\[
\theta_i (j,i) = \begin{cases} 
\theta_i (j,i) - \epsilon & \text{if victim} \\
\theta_i (j,i) + \phi & \text{if not victim}
\end{cases}
\]

- By sequentially replacing blocks of the same media stream, fragmentation of media streams can be avoided.
Simulation Model

Random network with 100 peers
- 40 media streams whose popularity follows a Zipf-like distribution with $\alpha = 1.0$
- The inter-arrival time between two successive requests for the first media stream follows the exponential distribution whose average is 20 minutes

Evaluation Criteria

Continuity of media play-out
Completeness of block retrieval
Completeness = \frac{Number of retrieved blocks in time}{Number of blocks in a media stream}

Evaluation Criteria

Completeness with 95% Confidence Interval

Conclusion and Future Work

Conclusion
- We discuss the media streaming on pure P2P networks
- We propose a bio-inspired cache replacement algorithm considering the balance between supply and demand for media streams
- Through simulation experiments, we have shown that our proposed cache replacement algorithm can accomplish continuous media play-out independent of media popularity

Future Work
- We evaluate proposed mechanisms in more realistic situations where a peer randomly joins and leaves our system