Cache Content Placement Using Triangular Network Coding

Presenter: Cong Liu

Pouya Ostovari, Abdallah Khreishah, and Jie Wu
Computer & Information Sciences Department,
Temple University, USA
Agenda

- Introduction
- Motivation
- Content placement algorithm
- Simulation
- Conclusion
Alice and Bob (No coding)

4 transmissions
Alice and Bob (Coding)

3 transmissions
Motivation

- Providing more amount of data to the users.
Setting

- $h$ video layers on the server: $p_1, \ldots, p_h$
- Layer $p_i$ is not useful without the layers with a smaller index.
Setting

- **Capacity** = size of the video layers

Objective: maximizing the total number of available layers.

\[
\max \sum_{i=1}^{h} \sum_{j=1}^{n} z_{ij}
\]
## Triangular Coding

- **Linear Coding**
  - $2^h - 1$ ways to code $h$ layers.
  - $(2^h - 1)^n$ different possible placements for $n$ caches.

- **Triangular network coding**
  - The encoded video layers are in the form $\sum_{j=1}^{k} \alpha_j p_j$.

<table>
<thead>
<tr>
<th>Original packets</th>
<th>Linear coding</th>
<th>Triangular coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_1$</td>
<td>$p_1, p_2, p_3$</td>
<td>$p_1$</td>
</tr>
<tr>
<td>$p_2$</td>
<td>$p_1 + p_2, p_1 + p_3, p_2 + p_3$</td>
<td>$p_1 + p_2$</td>
</tr>
<tr>
<td>$p_3$</td>
<td>$p_1 + p_2 + p_3$</td>
<td>$p_1 + p_2 + p_3$</td>
</tr>
</tbody>
</table>
Content Placement Algorithm

- The problem of efficient content placement on the caches is an NP-complete problem.
- The greedy algorithm fills-up the caches in rounds.
- In each round, we select a user and fill-up its adjacent caches.
- Selection rules
  - **Rule 1**: the user with the minimum degree.
  - **Rule 2**: the user with a larger number of filled-up caches.
  - **Rule 3**: the user whose adjacent caches have less cumulative ranks.
- The algorithm fills-up the empty adjacent caches to user \( u_i \) with a random linear combination of the first \( d_i - v_i + r_i \) video layers.
Example

- Step 1: user $u_1$ has the minimum degree.
  - $2-0+0=2$

- Step 2: user $u_2$ has 2 filled adjacent caches.
  - $3-2+2=3$

- Step 3: select $u_3$ or $u_4$ randomly (assume $u_3$).
  - $3-2+2=3$
Simulation Setting

- Simulator in the MATLAB environment.
- Comparison
  - Number of available layers to the users.
  - Average utility: the number of available layers to a user divided by its degree.
  - Fairness: we define unfairness as the average difference between the number of available layers to each user and the average number of available layers to the users.

\[
\begin{align*}
  f' & = \sum_{i=1}^{m} \frac{|q_i - e|}{m} \\
  e & = \frac{\sum_{i=1}^{m} q_i}{m} \\
  f & = \frac{1}{f'}
\end{align*}
\]
Simulations

- Number of caches: 5
- Number of layers: 4

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The problem of efficient content placement on the caches is known as an NP-complete problem. Triangular network coding can reduce the complexity of content placement compared to the general form of coding. We propose a heuristic algorithm to solve the problem.
Questions