Instantly Decodable Network Codes for Real-Time Applications

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Real-Time Applications with Wireless Broadcast
- Some applications that use wireless broadcast
  - Live video streaming
  - Multiplayer games
- Unique characteristics
  - Strict, urgent deadlines
  - Loss tolerant

Real-Time IDNC: Problem Formulation
- Problem Formulation
  - $m$ packets, broadcast by a source
  - $n$ users, interested in all packets
  - Each user received only a subset of packets
  - To recover loss:
    - What is a coded packet that is instantly decodable and innovative to the maximum number of users?

Example

```
<table>
<thead>
<tr>
<th>User</th>
<th>Packet 1</th>
<th>Packet 2</th>
<th>Packet 3</th>
<th>Packet 4</th>
<th>Packet 5</th>
<th>Packet 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>u1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>u2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>u3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
```

- $p_1 + p_2$ decodable by $u_2$ and $u_3$
- $p_2 + p_3$ decodable by all users

Real-Time IDNC $\equiv$ Integer Quadratic Programming

Max-Clique Algorithm
- Polynomial-time algorithm to find the maximum clique and optimal coded packet:
  - Examine all cliques that touch $j$ columns, $j$-close to $j^*$
  - Complexity: $O(n m^{j^*+\delta})$

Simulation results:
- Max-Clique outperforms all other algorithms at any loss rate

NP-Hardness
- Real-Time IDNC $\equiv$ Integer Quadratic Programming
- IQP is NP-Hard: Reduction from Exact Cover by 3-Sets

Problem Motivation: Packet Loss
- Key question: What is the best recovery (coded) packet given the unique characteristics of real-time applications?
  - Investigate instantly decodable network codes (IDNC)
  - Formulate the Real-Time IDNC problem
- Related work
  - Instantly decodable, opportunistic codes:
    - [Katti '08] [Keller '08] [Sadeghi '09] [Athanasiadou '12]
  - IDNC focuses on minimizing the completion delay: [Sorour '10, 11, 12]
  - Index coding and data exchange problems: [Birk '06] [El Rouayheb '10]