Reduced power expenditure in the minimum latency transmission scheduling problem

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Transmission Scheduling
Time is divided into frames and frames into time-slots. Simplest example is TDMA (as many slots as nodes, one node per slot).

Problem Statement:
Given N communication requests, assign a color (time-slot) to each request. For all requests sharing the same color specify the power levels such that each request can be handled correctly (based on the abstract interference model).

Formulation

Decision variables:
- Processing-time variables:
  \[ x_i(t) = \begin{cases} 1, & \text{if transmitter } i \text{ is processed at time } t \\ 0, & \text{otherwise} \end{cases} \]
- Power level variables:
  \[ p_i(t) \in \mathbb{R}^+ \]

Master problem (Model 1):

\[
\begin{align*}
\text{minimize} & \quad \tau = \max_{i \in \mathcal{T}} \sum_{t=1}^{D} t x_i(t) \\
\text{subject to} & \quad \sum_{t=1}^{D} x_i(t) \geq 1 \quad \forall i \in \mathcal{T} \\
& \quad x_i(t) \in \{0, 1\} \quad \forall i \in \mathcal{T}, \ t = 1, \ldots, D.
\end{align*}
\]

Sub-problem (Model 2):

\[
\begin{align*}
\text{minimize} & \quad \sum_{i \in \mathcal{T}} \sum_{t=1}^{D} p_i(t) \\
\text{subject to} & \quad x_i^*(t) = 0 \Rightarrow p_i(t) = 0 \quad \forall i \in \mathcal{T}, \ t = 1, \ldots, D, \\
& \quad x_i^*(t) = 1 \Rightarrow p_i(t) g_{ii} \geq \gamma_i \left( \sum_{j \in \mathcal{T}, j \neq i} g_{ij} p_j(t) + \nu_i \right) \\
& \quad \forall i \in \mathcal{T}, \ t = 1, \ldots, D, \ p_i(t) \geq 0 \quad \forall i \in \mathcal{T}, \ t = 1, \ldots, D.
\end{align*}
\]

Proposed algorithm

Algorithm 1 A Cutting plane approach for the “Minimum latency transmission scheduling with SINR constraints” problem

initialise
  \[ k = 1 \]
  Compute \( LB \) \{Lower bound, e.g., from [8]\}
  Compute \( UB \) \{Upper bound, e.g., from [8]\}
  \( feas = false \) \{feasibility indicator, obtained from solving the Subproblem (Model 3)\}

Add cuts to Model 2.

if \( LB < UB \) then

repeat

Solve Model 2 to get optimal values \( x^*(k) \) and \( MP^*(k) \).
Set \( LB = \max[MP^*(k), LB] \).
Solve Model 3 to check feasibility of SINR constraints.
if Model 3 is feasible then
  \( feas = true \)
else
  Add cuts of the form (9) to Model 2.
end if

\[ k = k + 1 \]

until \( feas = true \) or \( LB = UB \)

end if

\[ k = k - 1 \]

return \( LB, x^*(K) \).

Examples - Numerical evaluations

<table>
<thead>
<tr>
<th>No. of pairs</th>
<th>CPU time (sec)</th>
<th>% of time out</th>
<th>% power\text{cut} - power\text{master}</th>
</tr>
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<td>10</td>
<td>0.59</td>
<td>0</td>
<td>53%</td>
</tr>
<tr>
<td>20</td>
<td>44.70</td>
<td>0</td>
<td>3%</td>
</tr>
<tr>
<td>30</td>
<td>1840.18</td>
<td>3</td>
<td>1646%</td>
</tr>
<tr>
<td>40</td>
<td>N/A</td>
<td>4</td>
<td>2409%</td>
</tr>
</tbody>
</table>

TABLE I

Numerical results for finding the optimal solution to Model 1 using \( CP_{\text{cuts}} \) and \( CP_{\text{slots}} \).

CP cuts similar to \( CP_{\text{slots}} \) but upper and lower bounding techniques (as in [8]) are not used.

\( CP_{\text{cuts}} \) saves a lot of power, especially when the network is large, even though it does not guarantee to find the optimal configuration.

Conclusions

A Cutting Plane approach is proposed.
- Combines the minimum latency transmission scheduling problem
- Partitions the problem into a Master Problem and a Subproblem
- Aim to minimize the total power expenditure

References