SERVICE CENTRIC SCHEDULING WITH STRICT DEADLINES

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RICE
NETWORKS EXIST TO PROVIDE SERVICES

INELASTIC SERVICES

SERVICE QUEUES AND VALUES

Queue
Value
Schedule
Who should transmit?

NETFLIX
skype
EXTRADE
NETFLIX
How do we maximize the weighted sum value of completed service transmissions?
PROBLEM FORMULATION

\[ \max_x \sum_{i=1}^{N} x_i w_i \]

s.t. \[ \sum_{i=1}^{z} x_i t_i + \beta(z) c \leq T_l \quad \forall l \]

\[ \beta(z) = \max \{ i : x_{i, \text{Skype}} = 1 \} \leq z \]

\[ \sum_{i=1}^{z_l} x_i \leq \beta(z_{l, \text{E*TRADE}}, z_{l}) \]

\[ z_{\text{Netflix}} = 4 \]
PROBLEM FORMULATION

\[
\begin{align*}
\text{max}_{x} & \sum_{i=1}^{N} x_i w_i \\
\text{s.t.} & \sum_{i=1}^{z_l} x_i t_i + \beta(z_l) c \leq T_l \forall l
\end{align*}
\]

Queue

Solve via Dynamic Approach
<table>
<thead>
<tr>
<th>Fixed Queue Order</th>
<th>Can Reorder Queue</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Solve dual <strong>without</strong> penalty</td>
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</tr>
<tr>
<td>• Add probing penalty to all feasible solutions</td>
<td>• Reorder by minimum time first <strong>if</strong> transmitting</td>
</tr>
<tr>
<td>• Select <em>best</em> solution among remaining feasible solutions</td>
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</table>
OPPORTUNISTIC STRATEGY

· if service in queue *(Netflix)* transmits

· if service in queue *(Netflix)* **does not** transmit
Optimal Stopping Problems

Series of random variables are viewed and a decision to stop must be made to minimize an associated function


Ferguson, Thomas S. "Optimal Stopping and Applications." UCLA 2012
Stopping Problems

Series of random variables are viewed and a decision to stop must be made to minimize an associated function

In our case...

- Series = Probing order
- Random variables = Transmission times
- Stop = Transmit
- Function \( \min_i E[i\delta + t_i] \) \( Transmit \) if \( t_i \leq V^* \)


Ferguson, Thomas S. "Optimal Stopping and Applications." UCLA 2012
Shortest Time First
- Allowed to reorder by min E[t] first
- Follow new order and transmit

Weighted Proportionally Fair
- Share resources depending on weighted average of bits
- No penalty for skipping once share is finished

\[
\frac{\text{value of service } i \cdot \text{bits of service } i}{\sum_{\text{all values}} \text{value of service } j \cdot \text{bits of service } j} \cdot \text{Time}
\]
SIMULATION SETUP

- Fixed transmit power
- Gaussian channels
- Rate = \( \log(1+\text{SNR}) \)

Strategies
- Full Network Information (NI)
- Opportunistic
- Stopping

- Service values \( \{1,2,4,8\} \)
- Common deadline of 1 millisecond
- Weighted Proportionally Fair (WPF)
- Shortest Time First (STF)
• Packet length 1kb
• 20 microsecond probing time (e.g. 802.11 RTS/CTS)

Strategies saturate at different points
• Packet length 2kb
• 100 microsecond probing time (e.g. 4x4 MIMO)
• Full NI does not reorder

WPF benefits from skipping in order

- Packet length 2kb
- 20 microsecond probing time

Cost of computations can payoff
- Packet length 2kb
- 20 microsecond probing time
- Stopping (eventually) transmits more
- Full NI transmits less, but more valuable

More value for less transmissions
TAKEAWAY MESSAGE

- Quantitative value of service with strict deadlines and non-negligible probing time
- Overhead in transmissions and probing influences strategy selection

To consider...

What *is* the value of a service?