Aggregation with non-preemptive priority

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DTIM/SER

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1 Introduction
   - Network Calculus
   - Context
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   - Reduce the over approximation: intuition
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3 Conclusion and perspectives
   - Conclusion and Perspectives
Embedded Network

- Communicating avionic system
- Real-time applications
- Guarantee a correct behavior of real-time applications
- End-to-end delay bound
Methods

- Model checking
- Scheduling analysis (pathway)
- Real time calculus and Network calculus
Network Calculus

- Forma framework
- Model network elements by their impact on flows
- Constrain arrival and service curves
- Analyse performance, virtual delays, throughput
- Pessimistic existing results
- \( \Rightarrow \) Reduce the pessimism
Aggregation with non-preemptive priority

- A server with a strict service curve $\beta$ for two flows $R_H$ and $R_L$
- $R_H$ is $\alpha_H$ upper-constrained
- $R_H$ has higher non-preemptive priority than $R_L$
- $R_L$ has fixed packet size $l_L$
Previous works have been done on the strict priority policy
The effect of the non-preemption seems to be not well taken into account
  - When a non-preemptive flow is served, it benefits of the full speed of the server
  - The restriction imposed by the arrival curve of the high-priority flow with the consequence of limitation of its backlogged period
A server with a strict service curve $\beta$ for two flows $R_H$ and $R_L$

- $R_H$ is $\alpha_H$ upper-constrained
- $R_H$ has higher non-preemptive priority than $R_L$
- $R_L$ has fixed packet size $l_L$
- Service curve $\beta - \alpha_H - l_L$ for $R_L$
- **Self competitive term** $-l_L$
Reduce the over approximation: Intuition

\[ \beta - \alpha_H - l_L \]
Illustration of $\beta_2^{np}$
\[ \beta_{2}^{np}(t) = \min \{ i \times l_2, \]
\[ \quad \beta(s - t) - \beta(\chi'_i) + (i - 1)l_2, \]
\[ \quad \beta(s - t) - \beta(\chi''_i + \psi_2) + i \times l_2 \} \]

\[
\begin{align*}
\chi'_i &= \inf \{ t \mid \beta(t) - \alpha_1(t) - l_3 > (i - 1)l_2 \} \\
\chi''_i &= \inf \{ t \mid \beta(t + \psi_2) - \alpha_1(t + \psi_2) > i \times l_2 \} \\
\chi_i &= \max \{ \chi'_i, \chi''_i \}.
\end{align*}
\]

\[ \psi_2 = \inf \{ t \mid \beta(t) \geq l_2 \} \]
Reduce the over approximation: intuition

Theorem

Examples

New service curve

1. Aggregation with non-preemptive priority – DTIM/SER

<table>
<thead>
<tr>
<th>Service</th>
<th>$P_1^B$</th>
<th>$P_1^A$</th>
<th>$P_2^B$</th>
<th>$P_2^A$</th>
</tr>
</thead>
</table>

A–backlog

B–backlog

0 1 2 3 4 5 6 7
**StSc(t):** Start of service; **StBl:** Start of backlog

\[
\begin{align*}
\text{StBl}_2(t) & \quad t \quad \text{StSc}_2(t) \\
\text{StBl}_1(t) & \quad \text{StBl}_2(t) \quad t \quad \text{StSc}_2(t)
\end{align*}
\]

(a) \( R_3 \quad R_2 \) \( \leq \psi_3 \)

(c) \( R_1 \quad R_2 \) \( \leq \psi_1 \)
StSc(t): Start of service; StBl: Start of backlog

\[ StBl_2(t) \quad \downarrow \quad StBl_1(t) \quad t \quad StSc_1(t) \quad StSc_2(t) \]

\[ d) \quad \begin{array}{ccc}
R_3 & R_1 & R_2 \\
\leq \psi_3
\end{array} \]

\[ StBl_1(t) \quad \downarrow \quad StSc_1(t) \quad StBl_2(t) \quad StSc_2(t) \]

\[ e) \quad \begin{array}{ccc}
R_2 & R_1 & R_2 \\
\leq \psi_2 & \uparrow t
\end{array} \]
A server with a strict service curve $\beta$ for two flows $R_H$ and $R_L$

- $R_H$ is $\alpha_H$ upper-constrained
- $R_L$ is $\alpha_L$ upper-constrained and has fixed-size packets $l$
- $R_H$ has higher non-preemptive priority than $R_L$

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta(t)$</td>
<td>$3t-9$</td>
</tr>
<tr>
<td>$\alpha_H(t)$</td>
<td>$\begin{cases} t+2 &amp; \text{if } t \geq 0 \ 0 &amp; \text{else} \end{cases}$</td>
</tr>
<tr>
<td>$l$</td>
<td>$3$</td>
</tr>
<tr>
<td>$\alpha_L(t)$</td>
<td>$\lceil 3t \rceil$</td>
</tr>
</tbody>
</table>
## Results

### Table: Delays with the new result

<table>
<thead>
<tr>
<th>Virtual delay (ms)</th>
<th>$R_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing</td>
<td>10.5</td>
</tr>
<tr>
<td>[WM11]</td>
<td>7.5</td>
</tr>
</tbody>
</table>

![Graph showing comparisons between Ours and Existing with key points α, β, α_H, and α_L at times t=3, t=6.5, t=8, and t=10.5 with corresponding virtual delays.]
**[WM11] IS NOT TIGHT**

<table>
<thead>
<tr>
<th></th>
<th>Period</th>
<th>Size ( l_i )</th>
<th>( \alpha_i )</th>
<th>Exact worst delay</th>
<th>Delay [WM11]</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_1 )</td>
<td>2.5</td>
<td>2.5</td>
<td>( 2.5 \left\lceil \frac{2t}{5} \right\rceil )</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>( R_2 )</td>
<td>3.5</td>
<td>2.5</td>
<td>( 2.5 \left\lceil \frac{2t}{7} \right\rceil )</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>( R_3 )</td>
<td>3.5</td>
<td>2.5</td>
<td>( 2.5 \left\lceil \frac{2t}{7} \right\rceil )</td>
<td>3.5</td>
<td>6</td>
</tr>
</tbody>
</table>

**Table:** Example CAN \( \beta(t) = 2.5t \)
\( \beta_{2S}^{np}(t) = \min \{i \times l_2, \)
\[ \beta(t) - \beta(\chi'_{i}) + (i - 1) \times l_2, \]
\[ \beta(t) + \beta(\Delta + \psi_2) - \beta(\chi''_{i} + \psi_2) + (i - 1) \times l_2 \} \quad (1) \]

with \( i \) such that \( \chi(t) = \chi_i \) and \( \Delta = \alpha_{2}^{-1}(2 \times l_2) - \psi_2 \)

\[
\begin{align*}
\chi'_{i} & = \inf \{t | \beta(t) - \alpha_1(t) - l_3 > (i - 1)l_2\} \\
\chi''_{i} & = \inf \{t | \beta(t + \psi_2) - \alpha_1(t + \psi_2) > i \times l_2\}
\end{align*}
\]

\( \chi_i = \max \{\chi'_i, \chi''_i\} \).

\( \psi_2 = \inf \{t | \beta(t) \geq l_2\} \)
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<th>Exact worst delay</th>
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<th>New delay</th>
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**Table:** Example CAN \(\beta(t) = 2.5t\)
CONCLUSION

- Service guaranteed to the lower priority flows in a context of aggregation with non-preemptive priority within network calculus
- vs. other NC-based approaches
  - more general
  - always better
- vs. scheduling based:
  - more general
  - always the same result?
- Future works
  - exploit the fact that the result is more general (energy-aware processing, WFQ)
  - Is this result tight?
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Questions ?