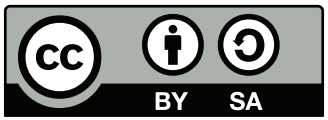
# Network Calculus Tests – Tandem Network Configurations

Version 1.1 (2014-Dec-30)



## General Information

- The network calculus analyses presented in this document were created for the purpose of testing the Disco Deterministic Network Calculator (DiscoDNC)[1] – an open-source deterministic network calculus tool developed by the *Distributed Computer Systems (DISCO) Lab* at the University of Kaiserslautern.
- Naming of the individual network configurations depicts the name of the according functional test for the DiscoDNC.
- The naming scheme used in this document is detailed in NetworkCalculus_NamingScheme.pdf.
- Arrival bound computations are equivalent to the `PbooArrivalBound_Output_PerHop.java` class of the DiscoDNC.
- The end-to-end left-over service curve for PBOO arrival bounds can be computed by simply convolving the server-local ones.
- Arrival bounds for `PmooArrivalBound.java` and analyses using them are listed only if results are different to PBOO.

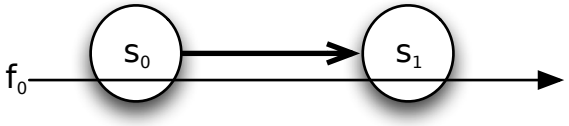
## Changelog:

Version 1.1 (2014-Dec-30):

- Streamlined the PMOO left-over latency $T_{\text{e2e}}^{\text{l.o.}f}$ computation.
- Adapted to naming scheme version 1.1.

[1] http://disco.cs.uni-kl.de/index.php/projects/disco-dnc

**Tandem_1SC_1Flow**




- $\beta_{s_0} = \beta_{s_1} = \beta_{R_{s_i},T_{s_i}} = \beta_{10,10},\ i \in \{0,1\}$
- $\mathcal{F} = \{f_0\}$
- $\alpha^{f_0} = \gamma_{r^{f_0},b^{f_0}} = \gamma_{5,25}$

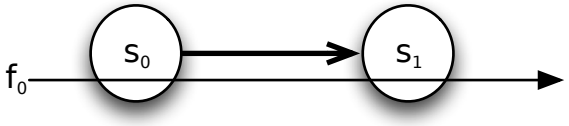
| $\text{arrivalBound}(s_1, \{f_0\}, \mathcal{G}), \mathcal{G} \in \mathcal{P}(\mathcal{F}) = \alpha_{s_1}^{f_0}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{f_0}$ | | $= \gamma_{5,25}$ | |
| $\alpha_{s_0}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{R_{s_0}^{\text{l.o.}f_0}, T_{s_0}^{\text{l.o.}f_0}}$ | | $= \beta_{10,10}$ | |
| $\alpha_{s_1}^{f_0} = \alpha^{f_0} \oslash \beta_{s_0}^{\text{l.o.}f_0} = \gamma_{r_{s_1}^{f_0}, b_{s_1}^{f_0}}$ | $r_{s_1}^{f_0}$ | $= 5$ | |
| | $b_{s_1}^{f_0}$ | $\alpha^{f_0}(T_{s_0}^{\text{l.o.}f_0}) = 5 \cdot 10 + 25 = 75$ | |
| | $=$ | $= \gamma_{5,75}$ | |

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha^{f_0}$ | $= \gamma_{5,25}$ | |
| | $D_{s_0}^{f_0}$ | $\beta_{s_0} = b_{s_0}$<br>$10 \cdot [t-10]^+ = 25$<br>$t = 12\frac{1}{2}$ | FIFO per mico flow<br>$\beta_{s_0} = b_{s_0}$<br>$10 \cdot [t-10]^+ = 25$<br>$t = 12\frac{1}{2}$ |
| | $B_{s_0}^{f_0}$ | $\alpha_{s_0}(T_{s_0}) = 5 \cdot 10 + 25$<br>$= 75$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{f_0}$ | $= \gamma_{5,75}$ | |
| | $D_{s_1}^{f_0}$ | $\beta_{s_1} = b_{s_1}$<br>$10 \cdot [t-10]^+ = 75$<br>$t = 17\frac{1}{2}$ | FIFO per micro flow<br>$\beta_{s_1} = b_{s_1}$<br>$10 \cdot [t-10]^+ = 75$<br>$t = 17\frac{1}{2}$ |
| | $B_{s_1}^{f_0}$ | $\alpha_{s_1}(T_{s_1}) = 5 \cdot 10 + 75$<br>$= 125$ | |
| $D^{f_0}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_0} = 30$ | |
| $B^{f_0}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_0} = 125$ | |

| SFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{s_0}$ | $= \beta_{10,10}$ | |
| $s_1$ | $\alpha_{s_1}^{x(f_0)}$ | $= \gamma_{0,0}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_0} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_0)} = \beta_{s_1}$ | $= \beta_{10,10}$ | |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{10,20}$ | |
| $D^{f_0}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$10 \cdot [t-20]^+ = 25$<br>$t = 22\frac{1}{2}$ | |
| $B^{f_0}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 20 + 25$<br>$= 125$ | |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ |
| $s_1$ | $\alpha_{s_0}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | $R_{\text{e2e}}^{\text{l.o.}f_0} = \bigwedge_{i \in \{0,1\}} \left( R_{s_i} - r_{s_i}^{x(f_0)} \right)$ | $= (10-0) \wedge (10-0)$<br>$= 10$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_0} = \sum_{i \in \{0,1\}} \left( T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_0)} + r_{s_i}^{x(f_0)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_0}} \right)$ | $= 10 + \frac{0+0\cdot 10}{10} + 10 + \frac{0+0\cdot 10}{10}$<br>$= 20$ |
| | $=$ | $= \beta_{10,20}$ |
| $D^{f_0}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$10 \cdot [t-20]^+ = 25$<br>$t = 22\frac{1}{2}$ |
| $B^{f_0}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 20 + 25$<br>$= 125$ |

**Tandem_2SCs_1Flow**




- $\beta_{s_0} = \beta_{R_{s_0},T_{s_0}} = \beta_{10,10}$
- $\beta_{s_1} = \beta_{R_{s_1},T_{s_1}} = \beta_{6,6}$
- $\mathcal{F} = \{f_0\}$
- $\alpha^{f_0} = \gamma_{r^{f_0},b^{f_0}} = \gamma_{5,25}$

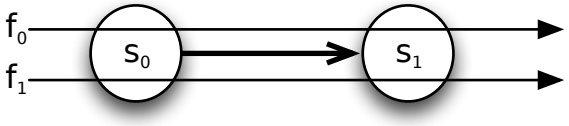
| $\text{arrivalBound}(s_1, \{f_0\}, \mathcal{G}), \mathcal{G} \in \mathcal{P}(\mathcal{F}) = \alpha_{s_1}^{f_0}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{f_0}$ | | $= \gamma_{5,25}$ | |
| $\alpha_{s_0}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{R_{s_0}^{\text{l.o.}f_0}, T_{s_0}^{\text{l.o.}f_0}}$ | | $= \beta_{10,10}$ | |
| $\alpha_{s_1}^{f_0} = \alpha^{f_0} \oslash \beta_{s_0}^{\text{l.o.}f_0} = \gamma_{r_{s_1}^{f_0}, b_{s_1}^{f_0}}$ | $r_{s_1}^{f_0}$ | $= 5$ | |
| | $b_{s_1}^{f_0}$ | $\alpha^{f_0}(T_{s_0}^{\text{l.o.}f_0}) = 5 \cdot 10 + 25 = 75$ | |
| | $=$ | $= \gamma_{5,75}$ | |

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha^{f_0}$ | $= \gamma_{5,25}$ | |
| | $D_{s_0}^{f_0}$ | $\beta_{s_0} = b_{s_0}$<br>$10 \cdot [t-10]^+ = 25$<br>$t = 12\frac{1}{2}$ | FIFO per micro flow<br>$\beta_{s_0} = b_{s_0}$<br>$10 \cdot [t-10]^+ = 25$<br>$t = 12\frac{1}{2}$ |
| | $B_{s_0}^{f_0}$ | $\alpha_{s_0}(T_{s_0}) = 5 \cdot 10 + 25$<br>$= 75$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{f_0}$ | $= \gamma_{5,75}$ | |
| | $D_{s_1}^{f_0}$ | $\beta_{s_1} = b_{s_1}$<br>$6 \cdot [t-6]^+ = 75$<br>$t = 18\frac{1}{2}$ | FIFO per micro flow<br>$\beta_{s_1} = b_{s_1}$<br>$6 \cdot [t-6]^+ = 75$<br>$t = 18\frac{1}{2}$ |
| | $B_{s_1}^{f_0}$ | $\alpha_{s_1}(T_{s_1}) = 5 \cdot 6 + 75$<br>$= 105$ | |
| $D^{f_0}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_0} = 31$ | |
| $B^{f_0}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_0} = 105$ | |

| SFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{s_0}$ | $= \beta_{10,10}$ | |
| $s_0 s_1$ | $\alpha_{s_0 s_1}^{x(f_0)}$ | $= \gamma_{0,0}$ | |
| $s_1$ | $\alpha_{s_1}^{x(f_0)} = \alpha_{s_0 s_1}^{x(f_0)}$ | $= \gamma_{0,0}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_0} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_0)} = \beta_{s_1}$ | $= \beta_{6,6}$ | |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{6,16}$ | |
| $D^{f_0}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$6 \cdot [t-16]^+ = 25$<br>$t = 20\frac{1}{6}$ | |
| $B^{f_0}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 16 + 25$<br>$= 105$ | |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | $R_{\text{e2e}}^{\text{l.o.}f_0} = \bigwedge_{i\in\{0,1\}} \left(R_{s_i} - r_{s_i}^{x(f_0)}\right)$ | $= (10-0) \wedge (6-0)$<br>$= 6$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_0} = \sum_{i\in\{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_0)} + r_{s_i}^{x(f_0)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_0}}\right)$ | $= 10 + \frac{0+0\cdot 10}{6} + 6 + \frac{0+0\cdot 6}{6}$<br>$= 16$ |
| | $=$ | $= \beta_{6,16}$ |
| $D^{f_0}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$6 \cdot [t-16]^+ = 25$<br>$t = 20\frac{1}{6}$ |
| $B^{f_0}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 16 + 25$<br>$= 105$ |

**Tandem_1SC_2Flows_1AC_1Path**




- $\beta_{s_0} = \beta_{s_1} = \beta_{R_{s_i},T_{s_i}} = \beta_{10,10},\ i \in \{0,1\}$
- $\mathcal{F} = \{f_0, f_1\}$
- $\alpha^{f_0} = \alpha^{f_1} = \gamma_{r^{f_n},b^{f_n}} = \gamma_{5,25},\ n \in \{0,1\}$

| $\text{arrivalBound}(s_1, \{f_0\}, \{f_1\}) = \alpha_{s_1}^{f_0}$ $= \text{arrivalBound}(s_1, \{f_1\}, \{f_0\}) = \alpha_{s_1}^{f_1}$ | FIFO_MUX | ARB_MUX |
|---|---|---|

| | | |
|---|---|---|
| $\alpha_{s_0}^{f_n}$ | | $= \gamma_{5,25}$ |
| $\alpha_{s_0}^{x f_n}$ | | $= \gamma_{0,0}$ |
| $\beta_{s_0}^{\text{l.o.} f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{x f_n} = \beta_{R_{s_0}^{\text{l.o.} f_n}, T_{s_0}^{\text{l.o.} f_n}}$ | | $= \beta_{10,10}$ |
| $\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\text{l.o.} f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$ | $r_{s_1}^{f_n}$ | $= 5$ |
| | $b_{s_1}^{f_n}$ | $\alpha^{f_0}(T_{s_0}^{\text{l.o.} f_0}) = 5 \cdot 10 + 25 = 75$ |
| | $=$ | $= \gamma_{5,75}$ |

| $\text{arrivalBound}(s_1, \{f_0, f_1\}, \{\}) = \alpha_{s_1}^{\{f_0,f_1\}}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|

| | | |
|---|---|---|
| $\alpha_{s_0}^{\{f_0,f_1\}}$ | | $= \gamma_{10,50}$ |
| $\alpha_{s_0}^{x\{f_0,f_1\}}$ | | $= \gamma_{0,0}$ |
| $\beta_{s_0}^{\text{l.o.}\{f_0,f_1\}} = \beta_{s_0} \ominus \alpha_{s_0}^{x\{f_0,f_1\}} = \beta_{R_{s_0}^{\text{l.o.}\{f_0,f_1\}}, T_{s_0}^{\text{l.o.}\{f_0,f_1\}}}$ | | $= \beta_{10,10}$ |
| $\alpha_{s_1}^{\{f_0,f_1\}} = \alpha_{s_0}^{\{f_0,f_1\}} \oslash \beta_{s_0}^{\text{l.o.}\{f_0,f_1\}} = \gamma_{r_{s_1}^{\{f_0,f_1\}}, b_{s_1}^{\{f_0,f_1\}}}$ | $r_{s_1}^{\{f_0,f_1\}}$ | $= 10$ |
| | $b_{s_1}^{\{f_0,f_1\}}$ | $\alpha_{s_0}^{\{f_0,f_1\}}(T_{s_0}^{\text{l.o.}\{f_0,f_1\}}) = 10 \cdot 10 + 50 = 150$ |
| | $=$ | $= \gamma_{10,150}$ |

**Flows $f_n$, $n \in \{0, 1\}$**

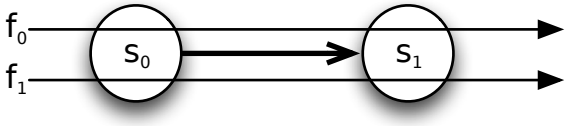
TFA results will be equal for all flows as they share the same path of servers.

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha^{f_0} + \alpha^{f_1}$ | $= \gamma_{10,50}$ | |
| | $D_{s_0}^{f_n}$ | $\beta_{s_0} = b_{s_0}$<br>$10 \cdot [t-10]^+ = 50$<br>$t = 15$ | $\beta_{s_0} = \alpha_{s_0}$<br>$10 \cdot [t-10]^+ = 10 \cdot t + 50$<br>$0 \cdot t = 150$<br>$\Rightarrow D_{s_0}^{f_n} = \infty$ |
| | $B_{s_0}^{f_n}$ | $\alpha_{s_0}(T_{s_0}) = 10 \cdot 10 + 50$<br>$= 150$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{\{f_0, f_1\}}$ | $= \gamma_{10,150}$ | |
| | $D_{s_1}^{f_n}$ | $\beta_{s_1} = b_{s_1}$<br>$10 \cdot [t-10]^+ = 150$<br>$t = 25$ | $\beta_{s_1} = \alpha_{s_1}$<br>$10 \cdot [t-10]^+ = 10 \cdot t + 150$<br>$0 \cdot t = 250$<br>$\Rightarrow D_{s_1}^{f_n} = \infty$ |
| | $B_{s_1}^{f_n}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 10 + 150$<br>$= 250$ | |
| $D^{f_n}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_n} = 40$ | $\sum_{i=0}^{1} D_{s_i}^{f_n} = \infty$ |
| $B^{f_n}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_n} = 250$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{5,25}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_n)}$ | $R_{s_0}^{\text{l.o.}f_n}$ | $= 5$ | |
| | | $T_{s_0}^{\text{l.o.}f_n}$ | $\beta_{s_0} = b_{s_0}^{xf_n}$<br>$10 \cdot [t-10]^+ = 25$<br>$t = 12\frac{1}{2}$ | $\beta_{s_0} = \alpha_{s_0}^{xf_n}$<br>$10 \cdot [t-10]^+ = 5 \cdot t + 25$<br>$t = 25$ |
| | | $=$ | $= \beta_{5,12\frac{1}{2}}$ | $= \beta_{5,25}$ |
| $s_1$ | $\alpha_{s_1}^{xf_n}$ | | $= \gamma_{5,75}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n}$ | $R_{s_1}^{\text{l.o.}f_n}$ | $= 5$ | |
| | | $T_{s_1}^{\text{l.o.}f_n}$ | $\beta_{s_1} = b_{s_1}^{xf_n}$<br>$10 \cdot [t-10]^+ = 75$<br>$t = 17\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}^{xf_n}$<br>$10 \cdot [t-10]^+ = 5 \cdot t + 75$<br>$t = 35$ |
| | | $=$ | $= \beta_{5,17\frac{1}{2}}$ | $= \beta_{5,35}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n}, T_{\text{e2e}}^{\text{l.o.}f_n}}$ | | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{5,30}$ | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{5,60}$ |
| $D^{f_n}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$5 \cdot [t-30]^+ = 25$<br>$t = 35$ | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$5 \cdot [t-60]^+ = 25$<br>$t = 65$ |
| $B^{f_n}$ | | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 5 \cdot 30 + 25$<br>$= 175$ | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 5 \cdot 60 + 25$<br>$= 325$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}f_n}$ | $= \gamma_{5,25}$ |
| | $\alpha_{s_0}^{xf_n}$ | $= \gamma_{5,25}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}f_n}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_1}^{xf_n}$ | $= \gamma_{5,75}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n}, T_{\text{e2e}}^{\text{l.o.}f_n}}$ | $R_{\text{e2e}}^{\text{l.o.}f_n} = \bigwedge_{i\in\{0,1\}} \left(R_{s_i} - r_{s_i}^{xf_n}\right)$ | $= (10-5) \wedge (10-5)$<br>$= 5$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_n} = \sum_{i\in\{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}f_n} + r_{s_i}^{xf_n} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_n}}\right)$ | $= 10 + \frac{25+5\cdot 10}{5} + 10 + \frac{0+5\cdot 10}{5}$<br>$= 45$ |
| | $=$ | $= \beta_{5,45}$ |
| $D^{f_n}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$5 \cdot [t-45]^+ = 25$<br>$t = 50$ |
| $B^{f_n}$ | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 5 \cdot 45 + 25$<br>$= 250$ |

**Tandem_2SCs_2Flows_1AC_1Path**




- $\beta_{s_0} = \beta_{R_{s_0},T_{s_0}} = \beta_{10,10}$
- $\beta_{s_1} = \beta_{R_{s_1},T_{s_1}} = \beta_{6,6}$
- $\mathcal{F} = \{f_0, f_1\}$
- $\alpha^{f_0} = \alpha^{f_1} = \gamma_{r^{f_n},b^{f_n}} = \gamma_{2\frac{1}{2},12\frac{1}{2}}$, $n \in \{0,1\}$

| $\text{arrivalBound}(s_1, \{f_0\}, \{f_1\}) = \alpha_{s_1}^{f_0}$<br>$= \text{arrivalBound}(s_1, \{f_1\}, \{f_0\}) = \alpha_{s_1}^{f_1}$ | FIFO_MUX | ARB_MUX |
|---|---|---|

| | | |
|---|---|---|
| $\alpha_{s_0}^{f_n}$ | | $= \gamma_{2\frac{1}{2},12\frac{1}{2}}$ |
| $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{0,0}$ |
| $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\text{l.o.}f_n}, T_{s_0}^{\text{l.o.}f_n}}$ | | $= \beta_{10,10}$ |
| $\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\text{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$ | $r_{s_1}^{f_n}$ | $= 2\frac{1}{2}$ |
| | $b_{s_1}^{f_n}$ | $\alpha^{f_n}(T_{s_0}^{\text{l.o.}f_n}) = 2\frac{1}{2} \cdot 10 + 12\frac{1}{2} = 37\frac{1}{2}$ |
| | $=$ | $= \gamma_{2\frac{1}{2},37\frac{1}{2}}$ |

| $\text{arrivalBound}(s_1, \{f_0, f_1\}, \{\}) = \alpha_{s_1}^{\{f_0,f_1\}}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|

| | | |
|---|---|---|
| $\alpha_{s_0}^{\{f_0,f_1\}}$ | | $= \gamma_{5,25}$ |
| $\alpha_{s_0}^{x\{f_0,f_1\}}$ | | $= \gamma_{0,0}$ |
| $\beta_{s_0}^{\text{l.o.}\{f_0,f_1\}} = \beta_{s_0} \ominus \alpha_{s_0}^{x\{f_0,f_1\}} = \beta_{R_{s_0}^{\text{l.o.}\{f_0,f_1\}}, T_{s_0}^{\text{l.o.}\{f_0,f_1\}}}$ | | $= \beta_{10,10}$ |
| $\alpha_{s_1}^{\{f_0,f_1\}} = \alpha_{s_0}^{\{f_0,f_1\}} \oslash \beta_{s_0}^{\text{l.o.}\{f_0,f_1\}} = \gamma_{r_{s_1}^{\{f_0,f_1\}}, b_{s_1}^{\{f_0,f_1\}}}$ | $r_{s_1}^{\{f_0,f_1\}}$ | $= 5$ |
| | $b_{s_1}^{\{f_0,f_1\}}$ | $\alpha_{s_0}^{\{f_0,f_1\}}(T_{s_0}^{\text{l.o.}\{f_0,f_1\}}) = 5 \cdot 10 + 25 = 75$ |
| | $=$ | $= \gamma_{5,75}$ |

**Flows $f_n$, $n \in \{0, 1\}$**

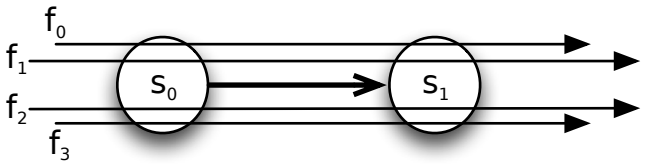
TFA results will be equal for all flows as they share the same path of servers.

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha^{f_0} + \alpha^{f_1}$ | $= \gamma_{5,25}$ | |
| | $D_{s_0}^{f_n}$ | $\beta_{s_0} = b_{s_0}$<br>$10 \cdot [t-10]^+ = 25$<br>$t = 12\frac{1}{2}$ | $\beta_{s_0} = \alpha_{s_0}$<br>$10 \cdot [t-10]^+ = 5 \cdot t + 25$<br>$t = 25$ |
| | $B_{s_0}^{f_n}$ | $\alpha_{s_0}(T_{s_0}) = 5 \cdot 10 + 25$<br>$= 75$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{\{f_0, f_1\}}$ | $= \gamma_{5,75}$ | |
| | $D_{s_1}^{f_n}$ | $\beta_{s_1} = b_{s_1}$<br>$6 \cdot [t-6]^+ = 75$<br>$t = 18\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$6 \cdot [t-6]^+ = 5 \cdot t + 75$<br>$t = 111$ |
| | $B_{s_1}^{f_n}$ | $\alpha_{s_1}(T_{s_1}) = 5 \cdot 6 + 75$<br>$= 105$ | |
| $D^{f_n}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_n} = 31$ | $\sum_{i=0}^{1} D_{s_i}^{f_n} = 136$ |
| $B^{f_n}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_n} = 105$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{2\frac{1}{2},12\frac{1}{2}}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n}$ | $R_{s_0}^{\text{l.o.}f_n}$ | $= 7\frac{1}{2}$ | |
| | | $T_{s_0}^{\text{l.o.}f_n}$ | $\beta_{s_0} = b_{s_0}^{xf_n}$<br>$10 \cdot [t-10]^+ = 12\frac{1}{2}$<br>$t = 11\frac{1}{4}$ | $\beta_{s_0} = \alpha_{s_0}^{xf_n}$<br>$10 \cdot [t-10]^+ = 2\frac{1}{2} \cdot t + 12\frac{1}{2}$<br>$t = 15$ |
| | | $=$ | $= \beta_{7\frac{1}{2},11\frac{1}{4}}$ | $= \beta_{7\frac{1}{2},15}$ |
| $s_1$ | $\alpha_{s_1}^{xf_n}$ | | $= \gamma_{2\frac{1}{2},37\frac{1}{2}}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n}$ | $R_{s_1}^{\text{l.o.}f_n}$ | $= 3\frac{1}{2}$ | |
| | | $T_{s_1}^{\text{l.o.}f_n}$ | $\beta_{s_1} = b_{s_1}^{xf_n}$<br>$6 \cdot [t-6]^+ = 37\frac{1}{2}$<br>$t = 12\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{xf_n}$<br>$6 \cdot [t-6]^+ = 2\frac{1}{2} \cdot t + 37\frac{1}{2}$<br>$t = 21$ |
| | | $=$ | $= \beta_{3\frac{1}{2},12\frac{1}{4}}$ | $= \beta_{3\frac{1}{2},21}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n}, T_{\text{e2e}}^{\text{l.o.}f_n}}$ | | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{3\frac{1}{2},23\frac{1}{2}}$ | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{3\frac{1}{2},36}$ |
| $D^{f_n}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$3\frac{1}{2} \cdot [t-23\frac{1}{2}]^+ = 12\frac{1}{2}$<br>$t = 27\frac{1}{14}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{j_i}$<br>$3\frac{1}{2} \cdot [t-36]^+ = 12\frac{1}{2}$<br>$t = 39\frac{4}{7}$ |
| $B^{f_n}$ | | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 2\frac{1}{2} \cdot 23\frac{1}{2} + 12\frac{1}{2}$<br>$= 71\frac{1}{4}$ | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 2\frac{1}{2} \cdot 36 + 12\frac{1}{2}$<br>$= 102\frac{1}{2}$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}f_n}$ | $= \gamma_{2\frac{1}{2},12\frac{1}{2}}$ |
| | $\alpha_{s_0}^{xf_n}$ | $= \gamma_{2\frac{1}{2},12\frac{1}{2}}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}f_n}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_1}^{xf_n}$ | $= \gamma_{2\frac{1}{2},37\frac{1}{2}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n},T_{\text{e2e}}^{\text{l.o.}f_n}}$ | $R_{\text{e2e}}^{\text{l.o.}f_n} = \bigwedge_{i\in\{0,1\}} \left(R_{s_i} - r_{s_i}^{xf_n}\right)$ | $= (10 - 2\frac{1}{2}) \wedge (6 - 2\frac{1}{2})$<br>$= 3\frac{1}{2}$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_n} = \sum_{i\in\{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}f_n} + r_{s_i}^{xf_n} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_n}}\right)$ | $= 6 + \frac{12\frac{1}{2} + 2\frac{1}{2} \cdot 10}{3\frac{1}{2}} + 10 + \frac{0 + 2\frac{1}{2} \cdot 10}{3\frac{1}{2}}$<br>$= 31$ |
| | $=$ | $= \beta_{3\frac{1}{2},31}$ |
| $D^{f_n}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$3\frac{1}{2} \cdot [t - 31]^+ = 12\frac{1}{2}$<br>$t = 34\frac{4}{7}$ |
| $B^{f_n}$ | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 2\frac{1}{2} \cdot 31 + 12\frac{1}{2}$<br>$= 90$ |

**Tandem_1SCs_4Flows_1ACs_1Path**




- $\beta_{s_0} = \beta_{s_1} = \beta_{R_{s_i},T_{s_i}} = \beta_{10,10},\ i \in \{0,1\}$
- $\mathcal{F} = \{f_0, f_1, f_2, f_3\}$
- $\alpha^{f_n} = \gamma_{r^{f_n},b^{f_n}} = \gamma_{2,10},\ n \in left\{0,1,2,3$

| $\text{arrivalBound}(s_1, xf_n, \{f_n\}) = \alpha_{s_1}^{xf_n},\ n \in \{0,1,2,3\}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{6,30}$ | |
| $\alpha_{s_0}^{xxf_n}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}xf_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xxf_n} = \beta_{R_{s_0}^{\text{l.o.}xf_n}, T_{s_0}^{\text{l.o.}xf_n}}$ | | $= \beta_{10,10}$ | |
| $\alpha_{s_1}^{xf_n} = \alpha_{s_0}^{xf_n} \oslash \beta_{s_0}^{\text{l.o.}xf_n} = \gamma_{r_{s_1}^{xf_n}, b_{s_1}^{xf_n}}$ | $r_{s_1}^{xf_n}$ | $= 6$ | |
| | $b_{s_1}^{xf_n}$ | $\alpha^{xf_n}(T_{s_0}^{\text{l.o.}xf_n}) = 6 \cdot 10 + 30 = 90$ | |
| | $=$ | $= \gamma_{6,90}$ | |

| $\text{arrivalBound}(s_1, \{f_0, f_1, f_2, f_3\}, \{\}) = \alpha_{s_1}^{\{f_0,f_1,f_2,f_3\}}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{\{f_0,f_1,f_2,f_3\}}$ | | $= \gamma_{8,40}$ | |
| $\alpha_{s_0}^{x\{f_0,f_1,f_2,f_3\}}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}\{f_0,f_1,f_2,f_3\}} = \beta_{s_0} \ominus \alpha_{s_0}^{x\{f_0,f_1,f_2,f_3\}} = \beta_{R_{s_0}^{\text{l.o.}\{f_0,f_1,f_2,f_3\}}, T_{s_0}^{\text{l.o.}\{f_0,f_1,f_2,f_3\}}}$ | | $= \beta_{10,10}$ | |
| $\alpha_{s_1}^{\{f_0,f_1,f_2,f_3\}} = \alpha_{s_0}^{\{f_0,f_1,f_2,f_3\}} \oslash \beta_{s_0}^{\text{l.o.}\{f_0,f_1,f_2,f_3\}} = \gamma_{r_{s_1}^{\{f_0,f_1,f_2,f_3\}}, b_{s_1}^{\{f_0,f_1,f_2,f_3\}}}$ | $r_{s_1}^{\{f_0,f_1,f_2,f_3\}}$ | $= 8$ | |
| | $b_{s_1}^{\{f_0,f_1,f_2,f_3\}}$ | $\alpha_{s_0}^{\{f_0,f_1,f_2,f_3\}}(T_{s_0}^{\text{l.o.}\{f_0,f_1,f_2,f_3\}}) = 8 \cdot 10 + 40 = 120$ | |
| | $=$ | $= \gamma_{8,120}$ | |

**Flows $f_n$, $n \in \{0,1,2,3\}$**

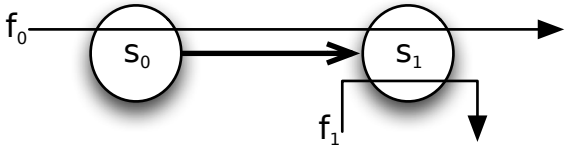
TFA results will be equal for all flows as they share the same path of servers.

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \sum_{n=0}^{3} \alpha^{f_n}$ | $= \gamma_{8,40}$ | |
| | $D_{s_0}^{f_n}$ | $\beta_{s_0} = b_{s_0}$<br>$10 \cdot [t-10]^+ = 40$<br>$t = 14$ | $\beta_{s_0} = \alpha_{s_0}$<br>$10 \cdot [t-10]^+ = 8 \cdot t + 40$<br>$t = 70$ |
| | $B_{s_0}^{f_n}$ | $\alpha_{s_0}(T_{s_0}) = 8 \cdot 10 + 40$<br>$= 120$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_1,f_2,f_3\}}$ | $= \gamma_{8,120}$ | |
| | $D_{s_1}^{f_n}$ | $\beta_{s_1} = b_{s_1}$<br>$10 \cdot [t-10]^+ = 120$<br>$t = 22$ | $\beta_{s_1} = \alpha_{s_1}$<br>$10 \cdot [t-10]^+ = 8 \cdot t + 120$<br>$t = 110$ |
| | $B_{s_1}^{f_n}$ | $\alpha_{s_1}(T_{s_1}) = 8 \cdot 10 + 120$<br>$= 200$ | |
| $D^{f_n}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_n} = 36$ | $\sum_{i=0}^{1} D_{s_i}^{f_n} = 180$ |
| $B^{f_n}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_n} = 200$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{xf_n} = \sum_{k=0}^{2} \alpha^{f_k}$ | | $= \gamma_{6,30}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n}$ | $R_{s_0}^{\text{l.o.}f_n}$ | $= 4$ | |
| | | $T_{s_0}^{\text{l.o.}f_n}$ | $\beta_{s_0} = b_{s_0}^{xf_n}$<br>$10 \cdot [t-10]^+ = 30$<br>$t = 13$ | $\beta_{s_0} = \alpha_{s_0}^{xf_n}$<br>$10 \cdot [t-10]^+ = 6 \cdot t + 30$<br>$t = 32\frac{1}{2}$ |
| | | $=$ | $= \beta_{4,13}$ | $= \beta_{4,32\frac{1}{2}}$ |
| $s_1$ | $\alpha_{s_1}^{xf_n} = \alpha_{s_1}^{xf_n}$ | | $= \gamma_{6,90}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n}$ | $R_{s_1}^{\text{l.o.}f_n}$ | $= 4$ | |
| | | $T_{s_1}^{\text{l.o.}f_n}$ | $\beta_{s_1} = b_{s_1}^{xf_n}$<br>$10 \cdot [t-10]^+ = 90$<br>$t = 19$ | $\beta_{s_1} = \alpha_{s_1}^{xf_n}$<br>$10 \cdot [t-10]^+ = 4 \cdot t + 90$<br>$t = 47\frac{1}{2}$ |
| | | $=$ | $= \beta_{4,19}$ | $= \beta_{4,47\frac{1}{2}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n}$ | | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{4,32}$ | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{4,80}$ |
| $D^{f_n}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$4 \cdot [t-32]^+ = 10$<br>$t = 34\frac{1}{2}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$4 \cdot [t-80]^+ = 10$<br>$t = 82\frac{1}{2}$ |
| $B^{f_n}$ | | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 2 \cdot 32 + 10$<br>$= 74$ | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 2 \cdot 80 + 10$<br>$= 170$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}f_n}$ | $= \gamma_{6,30}$ |
| | $\alpha_{s_0}^{xf_n}$ | $= \gamma_{6,30}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}f_n}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_1}^{xf_n}$ | $= \gamma_{6,90}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n}, T_{\text{e2e}}^{\text{l.o.}f_n}}$ | $R_{\text{e2e}}^{\text{l.o.}f_n} = \bigwedge_{i\in\{0,1\}} \left(R_{s_i} - r_{s_i}^{xf_n}\right)$ | $= (10-6) \wedge (10-6)$<br>$= 4$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_n} = \sum_{i\in\{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}f_n} + r_{s_i}^{xf_n} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_n}}\right)$ | $= 10 + \frac{30+6\cdot 10}{4} + 10 + \frac{0+6\cdot 10}{4}$<br>$= 37\frac{1}{2}$ |
| | $=$ | $= \beta_{3\frac{1}{2},31}$ |
| $D^{f_n}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$4 \cdot [t - 57\frac{1}{2}]^+ = 10$<br>$t = 60$ |
| $B^{f_n}$ | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 2 \cdot 57\frac{1}{2} + 10$<br>$= 125$ |

**Tandem_1SC_2Flows_1AC_2Paths**




- $\beta_{s_0} = \beta_{s_1} = \beta_{R_{s_i},T_{s_i}} = \beta_{20,20},\ i \in \{0,1\}$
- $\mathcal{F} = \{f_0, f_1\}$
- $\alpha^{f_0} = \alpha^{f_1} = \gamma_{r^{f_n},b^{f_n}} = \gamma_{5,25},\ n \in \{0,1\}$

| $\text{arrivalBound}(s_1, \{f_0\}, \mathcal{G})\ \mathcal{G} \in \mathcal{P}(\mathcal{F}) = \alpha_{s_1}^{f_0}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{f_0}$ | | $= \gamma_{5,25}$ | |
| $\alpha_{s_0}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{R_{s_0}^{\text{l.o.}f_0}, T_{s_0}^{\text{l.o.}f_0}}$ | | $= \beta_{10,10}$ | |
| $\alpha_{s_1}^{f_0} = \alpha_{s_0}^{f_0} \oslash \beta_{s_0}^{\text{l.o.}f_0} = \gamma_{r_{s_1}^{f_0}, b_{s_1}^{f_0}}$ | $r_{s_1}^{f_0}$ | $= 5$ | |
| | $b_{s_1}^{f_0}$ | $\alpha^{f_0}(T_{s_0}^{\text{l.o.}f_0}) = 5 \cdot 10 + 25 = 125$ | |
| | $=$ | $= \gamma_{5,125}$ | |

**Flow $f_0$**

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha^{f_0}$ | $= \gamma_{5,25}$ | |
| | $D_{s_0}^{f_0}$ | $\beta_{s_0} = b^{f_0}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | FIFO per micro flow<br>$\beta_{s_0} = b^{f_0}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ |
| | $B_{s_0}^{f_0}$ | $\alpha_{s_0}(T_{s_0}) = 5 \cdot 20 + 25$<br>$= 125$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{f_0}$ | $= \gamma_{5,25} + \gamma_{5,125} = \gamma_{10,150}$ | |
| | $D_{s_1}^{f_0}$ | $\beta_{s_1} = b_{s_1}$<br>$20 \cdot [t-20]^+ = 150$<br>$t = 27\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 150$<br>$t = 55$ |
| | $B_{s_1}^{f_0}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 150$<br>$= 350$ | |
| $D^{f_0}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_0} = 48\frac{3}{4}$ | $\sum_{i=0}^{1} D_{s_i}^{f_0} = 76\frac{1}{4}$ |
| $B^{f_0}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_0} = 350$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0}$ | | $= \beta_{20,20}$ | |
| $s_1$ | $\alpha_{s_1}^{x(f_0)} = \alpha_{s_1}^{f_1}$ | | $= \gamma_{5,25}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_0} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_0)}$ | $R_{s_1}^{\text{l.o.}f_0}$ | $= 15$ | |
| | | $T_{s_1}^{\text{l.o.}f_0}$ | $\beta_{s_1} = b_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | | $=$ | $= \beta_{15,21\frac{1}{4}}$ | $= \beta_{15,28\frac{1}{3}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,41\frac{1}{4}}$ | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,48\frac{1}{3}}$ |
| $D^{f_0}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t-41\frac{1}{4}]^+ = 25$<br>$t = 42\frac{11}{12}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t-48\frac{1}{3}]^+ = 25$<br>$t = 50$ |
| $B^{f_0}$ | | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 41\frac{1}{4} + 25$<br>$= 231\frac{1}{4}$ | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 48\frac{1}{3} + 25$<br>$= 266\frac{2}{3}$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}(f_0)}$ | $= \gamma_{5,25}$ |
| | $\alpha_{s_1}^{x(f_0)}$ | $= \gamma_{5,25}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | $R_{\text{e2e}}^{\text{l.o.}f_0} = \bigwedge_{i\in\{0,1\}} \left(R_{s_i} - r_{s_i}^{x(f_0)}\right)$ | $= (20-5) \wedge (20-5)$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_0} = \sum_{i\in\{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_0)} + r_{s_i}^{x(f_0)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_0}}\right)$ | $= 20 + \frac{0+0\cdot 20}{15} + 20 + \frac{25+5\cdot 20}{15}$<br>$= 48\frac{1}{3}$ |
| | $=$ | $= \beta_{15,48\frac{1}{3}}$ |
| $D^{f_0}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t - 48\frac{1}{3}]^+ = 25$<br>$t = 50$ |
| $B^{f_0}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 48\frac{1}{3} + 25$<br>$= 266\frac{2}{3}$ |

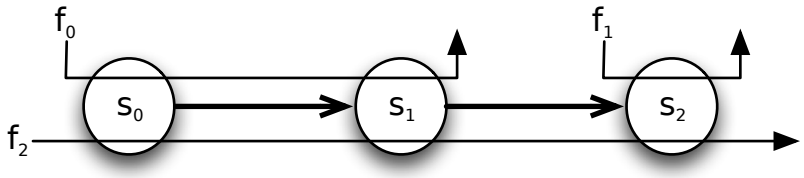
**Flow $f_1$**

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{f_1} + \alpha_{s_1}^{f_0}$ | $= \gamma_{5,25} + \gamma_{5,125} = \gamma_{10,150}$ | |
| | $D_{s_1}^{f_1}$ | $\beta_{s_1} = b_{s_1}$<br>$20 \cdot [t-20]^+ = 150$<br>$t = 27\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 150$<br>$t = 55$ |
| | $B_{s_1}^{f_1}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 150$<br>$= 350$ | |
| $D^{f_1}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_1} = 27\frac{1}{2}$ | $\sum_{i=0}^{1} D_{s_i}^{f_1} = 55$ |
| $B^{f_1}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_1} = 350$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_1$ | $\alpha_{s_1}^{x(f_1)} = \alpha_{s_1}^{f_0}$ | | $= \gamma_{5,125}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_1} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_1)} = \beta_{R_{s_1}^{\text{l.o.}f_1}, T_{s_1}^{\text{l.o.}f_1}}$ | $R_{s_1}^{\text{l.o.}f_1}$ | $= 15$ | |
| | | $T_{s_1}^{\text{l.o.}f_1}$ | $\beta_{s_1} = b_{s_1}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 125$<br>$t = 26\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 125$<br>$t = 35$ |
| | | $=$ | $= \beta_{15,26\frac{1}{4}}$ | $= \beta_{15,35}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_1}, T_{\text{e2e}}^{\text{l.o.}f_1}}$ | | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,26\frac{1}{4}}$ | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,35}$ |
| $D^{f_1}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t-26\frac{1}{4}]^+ = 25$<br>$t = 27\frac{11}{12}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t-35]^+ = 25$<br>$t = 36\frac{2}{3}$ |
| $B^{f_1}$ | | | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 26\frac{1}{4} + 25$<br>$= 156\frac{1}{4}$ | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 35 + 25$<br>$= 200$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_1$ | $\alpha_{s_1}^{\bar{x}(f_1)}$ | $= \gamma_{5,125}$ |
| | $\alpha_{s_1}^{x(f_1)}$ | $= \gamma_{5,125}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_1}, T_{\text{e2e}}^{\text{l.o.}f_1}}$ | $R_{\text{e2e}}^{\text{l.o.}f_1} = R_{s_1} - r_{s_1}^{x(f_1)}$ | $= 20 - 5$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_1} = T_{s_1} + \frac{b_{s_1}^{\bar{x}(f_1)} + r_{s_1}^{x(f_1)} \cdot T_{s_1}}{R_{\text{e2e}}^{\text{l.o.}f_0}}$ | $= 20 + \frac{125 + 5 \cdot 20}{15}$<br>$= 35$ |
| | $=$ | $= \beta_{15,35}$ |
| $D^{f_1}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t - 35]^+ = 25$<br>$t = 36\frac{2}{3}$ |
| $B^{f_1}$ | | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 35 + 25$<br>$= 200$ |

**Tandem_1SC_3Flows_1AC_3Paths**




- $\beta_{s_0} = \beta_{s_1} = \beta_{s_2} = \beta_{R_{s_i}, T_{s_i}} = \beta_{20,20}$, $i \in \{0, 1, 2\}$
- $\mathcal{F} = \{f_0, f_1, f_2\}$
- $\alpha^{f_0} = \alpha^{f_1} = \alpha^{f_2} = \gamma_{r^{f_n}, b^{f_n}} = \gamma_{5,25}$, $n \in \{0, 1, 2\}$

| $\text{arrivalBound}(s_1, \{f_0\}, \{f_2\}) = \alpha_{s_1}^{f_0}$ $= \text{arrivalBound}(s_1, \{f_2\}, \{f_0\}) = \alpha_{s_1}^{f_2}$ | FIFO_MUX | ARB_MUX |
|---|---|---|

| $\alpha_{s_0}^{f_n},\ n \in \{0,2\}$ | | $= \gamma_{5,25}$ |
|---|---|---|
| $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{0,0}$ |
| $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\text{l.o.}f_n}, T_{s_0}^{\text{l.o.}f_n}}$ | | $= \beta_{20,20}$ |
| $\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\text{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$ | $r_{s_1}^{f_n}$ | $= 5$ |
| | $b_{s_1}^{f_n}$ | $\alpha_{s_0}^{f_n}(T_{s_0}^{\text{l.o.}f_n}) = 5 \cdot 20 + 25 = 125$ |
| | $=$ | $= \gamma_{5,125}$ |

| $\text{arrivalBound}(s_1, \{f_0\}, \{f_0\}) = \alpha_{s_1}^{f_0}$ $= \text{arrivalBound}(s_1, \{f_2\}, \{f_2\}) = \alpha_{s_1}^{f_2}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{f_n},\ n \in \{0,2\}$ | | $= \gamma_{5,25}$ | |
| $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{5,25}$ | |
| $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\text{l.o.}f_n}, T_{s_0}^{\text{l.o.}f_n}}$ | $R_{s_0}^{\text{l.o.}f_n}$ | $= 15$ | |
| | $T_{s_0}^{\text{l.o.}f_n}$ | $\beta_{s_0} = b_{s_0}^{f_n}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | $\beta_{s_0} = \alpha_{s_0}^{f_n}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | $=$ | $= \beta_{15,21\frac{1}{4}}$ | $= \beta_{15,28\frac{1}{3}}$ |
| $\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\text{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$ | $r_{s_1}^{f_n}$ | $= 5$ | |
| | $b_{s_1}^{f_n}$ | $\alpha_{s_0}^{f_n}(T_{s_0}^{\text{l.o.}f_n}) = 131\frac{1}{4}$ | $\alpha_{s_0}^{f_n}(T_{s_0}^{\text{l.o.}f_n}) = 166\frac{2}{3}$ |
| | $=$ | $= \gamma_{5,131\frac{1}{4}}$ | $= \gamma_{5,166\frac{2}{3}}$ |

| $\text{arrivalBound}(s_1, \{f_0, f_2\}, \mathcal{G}),\ \mathcal{G} \in \mathcal{P}(\{f_1\}) = \alpha_{s_1}^{\{f_0,f_2\}}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{\{f_0,f_2\}}$ | | $= \gamma_{10,50}$ | |
| $\alpha_{s_0}^{x\{f_0,f_2\}}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}\{f_0,f_2\}} = \beta_{s_0} \ominus \alpha_{s_0}^{x\{f_0,f_2\}} = \beta_{R_{s_0}^{\text{l.o.}\{f_0,f_2\}}, T_{s_0}^{\text{l.o.}\{f_0,f_2\}}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_1}^{\{f_0,f_2\}} = \alpha_{s_0}^{\{f_0,f_2\}} \oslash \beta_{s_0}^{\text{l.o.}\{f_0,f_2\}} = \gamma_{r_{s_1}^{\{f_0,f_2\}}, b_{s_1}^{\{f_0,f_2\}}}$ | $r_{s_1}^{\{f_0,f_2\}}$ | $= 10$ | |
| | $b_{s_1}^{\{f_0,f_2\}}$ | $\alpha_{s_0}^{\{f_0,f_2\}}(T_{s_0}^{\text{l.o.}\{f_0,f_2\}}) = 10 \cdot 20 + 50 = 250$ | |
| | $=$ | $= \gamma_{10,250}$ | |

**PBOO-AB:**

| $\text{arrivalBound}(s_2, \{f_2\}, \mathcal{G}), \mathcal{G} \in \mathcal{P}(\{f_1\}) = \alpha_{s_2}^{f_2}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_1}^{f_2}$ | | $= \gamma_{5,131\frac{1}{4}}$ | $= \gamma_{5,166\frac{2}{3}}$ |
| $\alpha_{s_1}^{x(f_2)}$ | | $= \gamma_{5,131\frac{1}{4}}$ | $= \gamma_{5,166\frac{2}{3}}$ |
| $\beta_{s_1}^{\text{l.o.}f_2} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_2)} = \beta_{s_1} \ominus (\alpha_{s_0}^{f_0})^* = \beta_{R_{s_1}^{\text{l.o.}f_2}, T_{s_1}^{\text{l.o.}f_2}}$ | $R_{s_1}^{\text{l.o.}f_2}$ | $= 15$ | |
| | $T_{s_1}^{\text{l.o.}f_2}$ | $\beta_{s_1} = b_{s_0 s_1}^{f_0}$<br>$20 \cdot [t-20]^+ = 131\frac{1}{4}$<br>$t = 26\frac{9}{16}$ | $\beta_{s_1} = \alpha_{s_0 s_1}^{f_0}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 166\frac{2}{3}$<br>$t = 37\frac{7}{9}$ |
| | $=$ | $=\beta_{15,26\frac{9}{16}}$ | $=\beta_{15,37\frac{7}{9}}$ |
| $\alpha_{s_2}^{f_2} = \alpha_{s_1}^{f_2} \oslash \beta_{s_1}^{\text{l.o.}f_2} = \gamma_{r_{s_2}^{f_2}, b_{s_2}^{f_2}}$ | $r_{s_2}^{f_2}$ | $= 5$ | |
| | $b_{s_2}^{f_2}$ | $\alpha_{s_1}^{f_2}(T_{s_1}^{\text{l.o.}f_2}) = 5 \cdot 26\frac{9}{16} + 131\frac{1}{4} = 264\frac{1}{16}$ | $\alpha_{s_1}^{f_2}(T_{s_1}^{\text{l.o.}f_2}) = 5 \cdot 37\frac{7}{9} + 166\frac{2}{3} = 355\frac{5}{9}$ |
| | $=$ | $= \gamma_{5,264\frac{1}{16}}$ | $= \gamma_{5,355\frac{5}{9}}$ |

**PMOO-AB, ARB_MUX:**

$$\alpha_{s_2}^{f_2} = \alpha^{f_2} \oslash \beta_{\langle s_0, s_1 \rangle}^{\mathbf{l.o.}f_2}$$

Note, that we use a simplified notation here due to the use of rate-latencies and token-buckets as well as the lack of demultiplexing on the analyzed path.

$$\begin{aligned}
\beta_{\langle s_0, s_1 \rangle}^{\mathbf{l.o.}f_2} &= (\beta_{s_0} \otimes \beta_{s_1}) \ominus \alpha^{f_0} \\
&= (\beta_{20,20} \otimes \beta_{20,20}) \ominus \gamma_{5,25} \\
&= \beta_{20,40} \ominus \gamma_{5,25} \\
&= \beta_{15,55}
\end{aligned}$$

$$\begin{aligned}
\alpha_{s_2}^{f_2} &= \alpha^{f_2} \oslash \beta_{\langle s_0, s_1 \rangle}^{\mathbf{l.o.}f_2} \\
&= \gamma_{5,25} \oslash \beta_{15,55} \\
&= \gamma_{5,300}
\end{aligned}$$

| $\text{arrivalBound}(s_2, \{f_2\}, \mathcal{G}),\ \mathcal{G} \in \mathcal{P}(\{f_1\}) = \alpha_{s_2}^{f_2}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_1}^{f_2}$ | | $= \gamma_{5,131\frac{1}{4}}$ | $= \gamma_{5,166\frac{2}{3}}$ |
| $\alpha_{s_1}^{x(f_2)}$ | | $= \gamma_{5,131\frac{1}{4}}$ | $= \gamma_{5,166\frac{2}{3}}$ |
| $\beta_{s_1}^{\text{l.o.}f_2} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_2)} = \beta_{s_1} \ominus (\alpha_{s_0}^{f_0})^* = \beta_{R_{s_1}^{\text{l.o.}f_2}, T_{s_1}^{\text{l.o.}f_2}}$ | $R_{s_1}^{\text{l.o.}f_2}$ | $= 15$ | |
| | $T_{s_1}^{\text{l.o.}f_2}$ | $\beta_{s_1} = b_{s_0 s_1}^{f_0}$<br>$20 \cdot [t-20]^+ = 131\frac{1}{4}$<br>$t = 26\frac{9}{16}$ | $\beta_{s_1} = \alpha_{s_0 s_1}^{f_0}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 166\frac{2}{3}$<br>$t = 37\frac{7}{9}$ |
| | $=$ | $=\beta_{15,26\frac{9}{16}}$ | $=\beta_{15,37\frac{7}{9}}$ |
| $\alpha_{s_2}^{f_2} = \alpha_{s_1}^{f_2} \oslash \beta_{s_1}^{\text{l.o.}f_2} = \gamma_{r_{s_2}^{f_2}, b_{s_2}^{f_2}}$ | $r_{s_2}^{f_2}$ | $= 5$ | |
| | $b_{s_2}^{f_2}$ | $\alpha_{s_1}^{f_2}(T_{s_1}^{\text{l.o.}f_2}) = 5 \cdot 26\frac{9}{16} + 131\frac{1}{4} = 264\frac{1}{16}$ | $\alpha_{s_1}^{f_2}(T_{s_1}^{\text{l.o.}f_2}) = 5 \cdot 37\frac{7}{9} + 166\frac{2}{3} = 355\frac{5}{9}$ |
| | $=$ | $= \gamma_{5,264\frac{1}{16}}$ | $= \gamma_{5,355\frac{5}{9}}$ |

**Flow $f_0$ (comparable to Tandem_1SC_2Flows_1AC_1Path)**

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha^{f_0} + \alpha^{f_1}$ | $= \gamma_{10,50}$ | |
| | $D_{s_0}^{f_0}$ | $\beta_{s_0} = b_{s_0}$<br>$20 \cdot [t-20]^+ = 50$<br>$t = 22\frac{1}{2}$ | $\beta_{s_0} = \alpha_{s_0}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 50$<br>$t = 45$ |
| | $B_{s_0}^{f_0}$ | $\alpha_{s_0}(T_{s_0}) = 20 \cdot 10 + 50$<br>$= 250$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_2\}}$ | $= \gamma_{10,250}$ | |
| | $D_{s_1}^{f_0}$ | $\beta_{s_1} = b_{s_1}$<br>$20 \cdot [t-20]^+ = 250$<br>$t = 32\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 250$<br>$t = 65$ |
| | $B_{s_1}^{f_0}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 250$<br>$= 450$ | |
| $D^{f_0}$ | | $\sum_{i=0}^{1} D_{s_i}^{f_0} = 55$ | $\sum_{i=0}^{1} D_{s_i}^{f_0} = 110$ |
| $B^{f_0}$ | | $\max_{i=\{0,1\}} b_{s_i}^{f_0} = 450$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{x(f_0)} = \alpha^{f_2}$ | | $= \gamma_{5,25}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)}$ | $R_{s_0}^{\text{l.o.}f_0}$ | $= 5$ | |
| | | $T_{s_0}^{\text{l.o.}f_0}$ | $\beta_{s_0} = b_{s_0}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | $\beta_{s_0} = \alpha_{s_0}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | | $=$ | $= \beta_{15,21\frac{1}{4}}$ | $= \beta_{15,28\frac{1}{3}}$ |
| $s_1$ | $\alpha_{s_1}^{x(f_0)} = \alpha_{s_1}^{x(f_0)}$ | | $= \gamma_{5,125}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_0} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_0)}$ | $R_{s_1}^{\text{l.o.}f_0}$ | $= 15$ | |
| | | $T_{s_1}^{\text{l.o.}f_0}$ | $\beta_{s_1} = b_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 125$<br>$t = 26\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 125$<br>$t = 35$ |
| | | $=$ | $= \beta_{15,26\frac{1}{4}}$ | $= \beta_{15,35}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | | | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,47\frac{1}{2}}$ | $\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,63\frac{1}{3}}$ |
| $D^{f_0}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t-47\frac{1}{2}]^+ = 25$<br>$t = 49\frac{1}{6}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t-63\frac{1}{3}]^+ = 25$<br>$t = 65$ |
| $B^{f_0}$ | | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 47\frac{1}{2} + 25$<br>$= 262\frac{1}{2}$ | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 63\frac{1}{3} + 25$<br>$= 341\frac{2}{3}$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}(f_0)}$ | $= \gamma_{5,25}$ |
| | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{5,25}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_1}^{x(f_0)}$ | $= \gamma_{5,125}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | $R_{\text{e2e}}^{\text{l.o.}f_0} = \bigwedge_{i\in\{0,1\}} \left(R_{s_i} - r_{s_i}^{x(f_0)}\right)$ | $= (20-5) \wedge (20-5)$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_0} = \sum_{i\in\{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_0)} + r_{s_i}^{x(f_0)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_0}}\right)$ | $= 20 + \frac{25+5\cdot 20}{15} + 20 + \frac{0+5\cdot 20}{15}$<br>$= 55$ |
| | $=$ | $= \beta_{15,55}$ |
| $D^{f_0}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t-55]^+ = 25$<br>$t = 56\frac{2}{3}$ |
| $B^{f_0}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 55 + 25$<br>$= 300$ |

**Flow $f_1$ (comparable with Node_2Flows_2ACs)**

**PBOO-AB:**

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_2$ | $\alpha_{s_2} = \alpha^{f_1} + \alpha^{f_2}_{s_1 s_2}$ | $\gamma_{5,25} + \gamma_{5,264\frac{1}{16}} = \gamma_{10,289\frac{1}{16}}$ | $\gamma_{5,25} + \gamma_{5,355\frac{5}{9}} = \gamma_{10,380\frac{5}{9}}$ |
| | $D^{f_1}_{s_2}$ | $\beta_{s_2} = b_{s_2}$<br>$20 \cdot [t-20]^+ = 289\frac{1}{16}$<br>$t = 34\frac{29}{64}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 380\frac{5}{9}$<br>$t = 78\frac{5}{90}$ |
| | $B^{f_1}_{s_2}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 289\frac{1}{16}$<br>$= 489\frac{1}{16}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 380\frac{5}{9}$<br>$= 580\frac{5}{9}$ |
| $D^{f_1}$ | | $= 34\frac{29}{64}$ | $= 78\frac{5}{90}$ |
| $B^{f_1}$ | | $= 489\frac{1}{16}$ | $= 580\frac{5}{9}$ |

**PMOO-AB:**

| TFA | | ARB_MUX |
|---|---|---|
| $s_2$ | $\alpha_{s_2} = \alpha^{f_1} + \alpha^{f_2}_{s_1 s_2}$ | $\gamma_{5,25} + \gamma_{5,300} = \gamma_{10,325}$ |
| | $D^{f_1}_{s_2}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 325$<br>$t = 72\frac{1}{2}$ |
| | $B^{f_1}_{s_2}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 325$<br>$= 525$ |
| $D^{f_1}$ | | $= 72\frac{1}{2}$ |
| $B^{f_1}$ | | $= 525$ |

**PBOO-AB:**

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_2$ | $\alpha_{s_2}^{x(f_1)} = \alpha_{s_2}^{f_2}$ | | $= \gamma_{5,264\frac{1}{16}}$ | $= \gamma_{5,355\frac{5}{9}}$ |
| | $\beta_{s_2}^{\text{l.o.}f_1} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_1)} = \beta_{s_2} \ominus \alpha_{s_1 s_2}^{x(f_1)}$ | $R_{s_2}^{\text{l.o.}f_1}$ | $= 15$ | |
| | | $T_{s_2}^{\text{l.o.}f_1}$ | $\beta_{s_2} = b_{s_2}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 264\frac{1}{16}$<br>$t = 33\frac{13}{64}$ | $\beta_{s_2} = \alpha_{s_2}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 355\frac{5}{9}$<br>$t = 50\frac{10}{27}$ |
| | | $=$ | $=\beta_{15,33\frac{13}{64}}$ | $=\beta_{15,50\frac{10}{27}}$ |

| | | |
|---|---|---|
| $\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{s_2}^{\text{l.o.}f_1}$ | $=\beta_{15,33\frac{13}{64}}$ | $=\beta_{15,50\frac{10}{27}}$ |
| $D^{f_1}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t-33\frac{13}{64}]^+ = 25$<br>$t = 34\frac{167}{192}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t-50\frac{10}{27}]^+ = 25$<br>$t = 52\frac{1}{27}$ |
| $B^{f_1}$ | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 33\frac{13}{64} + 25$<br>$= 191\frac{1}{64}$ | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 50\frac{10}{27} + 25$<br>$= 276\frac{23}{27}$ |

**PMOO-AB:**

| SFA | | | ARB_MUX |
|---|---|---|---|
| $s_2$ | $\alpha_{s_2}^{x(f_1)} = \alpha_{s_2}^{f_2}$ | | $= \gamma_{5,300}$ |
| | $\beta_{s_2}^{\text{l.o.}f_1} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_1)} = \beta_{s_2} \ominus \alpha_{s_1 s_2}^{x(f_1)}$ | $R_{s_2}^{\text{l.o.}f_1}$ | $= 15$ |
| | | $T_{s_2}^{\text{l.o.}f_1}$ | $\beta_{s_2} = \alpha_{s_2}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 300$<br>$t = 46\frac{2}{3}$ |
| | | $=$ | $=\beta_{15,46\frac{2}{3}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{s_2}^{\text{l.o.}f_1}$ | | | $=\beta_{15,46\frac{2}{3}}$ |
| $D^{f_1}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t - 46\frac{2}{3}]^+ = 25$<br>$t = 48\frac{1}{3}$ |
| $B^{f_1}$ | | | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 46\frac{2}{3} + 25$<br>$= 258\frac{1}{3}$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_2$ | $\alpha_{s_2}^{\bar{x}(f_1)}$ | $= \gamma_{5,355\frac{5}{9}}$ |
| | $\alpha_{s_2}^{x(f_1)}$ | $= \gamma_{5,355\frac{5}{9}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_1}, T_{\text{e2e}}^{\text{l.o.}f_1}}$ | $R_{\text{e2e}}^{\text{l.o.}f_1} = R_{s_2} - r_{s_2}^{x(f_0)}$ | $= 20 - 5$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_1} = T_{s_2} + \frac{b_{s_2}^{\bar{x}(f_1)} + r_{s_2}^{x(f_1)} \cdot T_{s_2}}{R_{\text{e2e}}^{\text{l.o.}f_1}}$ | $= 20 + \frac{355\frac{5}{9} + 5 \cdot 20}{15}$<br>$= 50\frac{10}{27}$ |
| | $=$ | $= \beta_{15,50\frac{10}{27}}$ |
| $D^{f_1}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t - 50\frac{10}{27}]^+ = 25$<br>$t = 52\frac{1}{27}$ |
| $B^{f_1}$ | | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 50\frac{10}{27} + 25$<br>$= 276\frac{23}{27}$ |

**Flow $f_2$**

**PBOO-AB:**

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha_{s_0}^{f_0} + \alpha_{s_0}^{f_1}$ | $= \gamma_{10,50}$ | |
| | $D_{s_0}^{f_2}$ | $\beta_{s_0} = b_{s_0}$<br>$20 \cdot [t-20]^+ = 50$<br>$t = 22\frac{1}{2}$ | $\beta_{s_0} = \alpha_{s_0}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 50$<br>$t = 45$ |
| | $B_{s_0}^{f_2}$ | $\alpha_{s_0}(T_{s_0}) = 20 \cdot 10 + 50$<br>$= 250$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_1\}}$ | $= \gamma_{10,250}$ | |
| | $D_{s_1}^{f_2}$ | $\beta_{s_1} = b_{s_1}$<br>$20 \cdot [t-20]^+ = 250$<br>$t = 32\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 250$<br>$t = 65$ |
| | $B_{s_1}^{f_2}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 250$<br>$= 450$ | |
| $s_2$ | $\alpha_{s_2} = \alpha_{s_2}^{f_1} + \alpha_{s_2}^{f_2}$ | $\gamma_{5,25} + \gamma_{5,264\frac{1}{16}} = \gamma_{10,289\frac{1}{16}}$ | $\gamma_{5,25} + \gamma_{5,355\frac{5}{9}} = \gamma_{10,380\frac{5}{9}}$ |
| | $D_{s_2}^{f_2}$ | $\beta_{s_2} = b_{s_2}$<br>$20 \cdot [t-20]^+ = 289\frac{1}{16}$<br>$t = 34\frac{29}{64}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 380\frac{5}{9}$<br>$t = 78\frac{5}{90}$ |
| | $B_{s_2}^{f_2}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 289\frac{1}{16}$<br>$= 489\frac{1}{16}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 380\frac{5}{9}$<br>$= 580\frac{5}{9}$ |
| $D^{f_2}$ | | $\sum_{i=0}^{2} D_{s_i}^{f_2} = 89\frac{29}{64}$ | $\sum_{i=0}^{2} D_{s_i}^{f_2} = 188\frac{5}{90}$ |
| $B^{f_2}$ | | $\max_{i=\{0,1,2\}} b_{s_i}^{f_0} = 489\frac{1}{16}$ | $\max_{i=\{0,1,2\}} b_{s_i}^{f_0} = 580\frac{5}{9}$ |

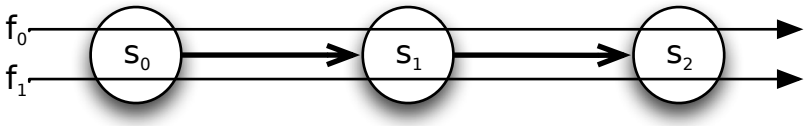
**PMOO-AB:**

| TFA | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha_{s_0}^{f_0} + \alpha_{s_0}^{f_1}$ | $= \gamma_{10,50}$ |
| | $D_{s_0}^{f_2}$ | $\beta_{s_0} = \alpha_{s_0}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 50$<br>$t = 45$ |
| | $B_{s_0}^{f_2}$ | $\alpha_{s_0}(T_{s_0}) = 20 \cdot 10 + 50$<br>$= 250$ |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_1\}}$ | $= \gamma_{10,250}$ |
| | $D_{s_1}^{f_2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 250$<br>$t = 65$ |
| | $B_{s_1}^{f_2}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 250$<br>$= 450$ |
| $s_2$ | $\alpha_{s_2} = \alpha^{f_1} + \alpha_{s_1 s_2}^{f_2}$ | $\gamma_{5,25} + \gamma_{5,300} = \gamma_{10,325}$ |
| | $D_{s_2}^{f_1}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 325$<br>$t = 72\frac{1}{2}$ |
| | $B_{s_2}^{f_1}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 325$<br>$= 525$ |
| $D^{f_2}$ | | $\sum_{i=0}^{2} D_{s_i}^{f_2} = 182\frac{1}{2}$ |
| $B^{f_2}$ | | $\max_{i=\{0,1,2\}} b_{s_i}^{f_0} = 525$ |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{x(f_2)} = \alpha_{s_0}^{f_0}$ | | $= \gamma_{5,25}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_2} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_2)} = \beta_{s_0} \ominus \alpha_{s_0}^{f_0}$ | $R_{s_0}^{\text{l.o.}f_2}$ | $= 5$ | |
| | | $T_{s_0}^{\text{l.o.}f_2}$ | $\beta_{s_0} = b_{s_0}^{x(f_2)}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | $\beta_{s_0} = \alpha_{s_0}^{x(f_2)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | | $=$ | $= \beta_{15,21\frac{1}{4}}$ | $= \beta_{15,28\frac{1}{3}}$ |
| $s_1$ | $\alpha_{s_1}^{x(f_2)} = \alpha_{s_1}^{x(f_2)}$ | | $= \gamma_{5,125}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_2} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_2)}$ | $R_{s_1}^{\text{l.o.}f_2}$ | $= 15$ | |
| | | $T_{s_1}^{\text{l.o.}f_2}$ | $\beta_{s_1} = b_{s_1}^{x(f_2)}$<br>$20 \cdot [t-20]^+ = 125$<br>$t = 26\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{x(f_2)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 125$<br>$t = 35$ |
| | | $=$ | $= \beta_{15,26\frac{1}{4}}$ | $= \beta_{15,35}$ |
| $s_2$ | $\alpha_{s_2}^{x(f_2)} = \alpha_{s_2}^{f_1}$ | | $= \gamma_{5,25}$ | |
| | $\beta_{s_2}^{\text{l.o.}f_2} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_2)} = \beta_{s_2} \ominus \alpha^{f_1}$ | $R_{s_2}^{\text{l.o.}f_2}$ | $= 15$ | |
| | | $T_{s_2}^{\text{l.o.}f_2}$ | $\beta_{s_2} = b_{s_2}^{x(f_2)}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | $\beta_{s_2} = \alpha_{s_2}^{x(f_2)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | | $=$ | $= \beta_{15,21\frac{1}{4}}$ | $= \beta_{15,28\frac{1}{3}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_2}$ | | | $\bigotimes_{i=0}^{2} \beta_{s_i}^{\text{l.o.}f_2} = \beta_{15,68\frac{3}{4}}$ | $\bigotimes_{i=0}^{2} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,91\frac{2}{3}}$ |
| $D^{f_2}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_2} = b^{f_2}$<br>$15 \cdot [t - 68\frac{3}{4}]^+ = 25$<br>$t = 70\frac{5}{12}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_2} = b^{f_2}$<br>$15 \cdot [t - 91\frac{2}{3}]^+ = 25$<br>$t = 93\frac{1}{3}$ |
| $B^{f_2}$ | | | $\alpha^{f_2}(T_{s_2}^{\text{l.o.}f_2}) = 5 \cdot 68\frac{3}{4} + 25$<br>$= 368\frac{3}{4}$ | $\alpha^{f_2}(T_{\text{e2e}}^{\text{l.o.}f_2}) = 5 \cdot 91\frac{2}{3} + 25$<br>$= 483\frac{1}{3}$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}(f_2)}$ | $= \gamma_{5,25}$ |
| | $\alpha_{s_0}^{x(f_2)}$ | $= \gamma_{5,25}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}(f_2)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_1}^{x(f_2)}$ | $= \gamma_{5,125}$ |
| $s_2$ | $\alpha_{s_2}^{\bar{x}(f_2)}$ | $= \gamma_{5,25}$ |
| | $\alpha_{s_2}^{x(f_2)}$ | $= \gamma_{5,25}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_2} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_2}, T_{\text{e2e}}^{\text{l.o.}f_2}}$ | $R_{\text{e2e}}^{\text{l.o.}f_2} = \bigwedge_{i\in\{0,1,2\}} \left(R_{s_i} - r_{s_i}^{x(f_2)}\right)$ | $= (20-5) \wedge (20-5) \wedge (20-5)$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_2} = \sum_{i\in\{0,1,2\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_2)} + r_{s_i}^{x(f_2)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_0}}\right)$ | $= 20 + \frac{25+5\cdot 20}{15} + 20 + \frac{0+5\cdot 20}{15} + 20 + \frac{25+5\cdot 20}{15}$<br>$= 83\frac{1}{3}$ |
| | $=$ | $= \beta_{15,83\frac{1}{3}}$ |
| $D^{f_2}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_2} = b^{f_1}$<br>$15 \cdot [t - 83\frac{1}{3}] = 25$<br>$t = 85$ |
| $B^{f_2}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 83\frac{1}{3} + 25$<br>$= 441\frac{2}{3}$ |

**Tandem_1SC_2Flows_1AC_1Path_v2**




- $\beta_{s_0} = \beta_{s_1} = \beta_{s_2} = \beta_{R_{s_i},T_{s_i}} = \beta_{20,20},\ i \in \{0,1\}$
- $\mathcal{F} = \{f_0, f_1\}$
- $\alpha^{f_0} = \alpha^{f_1} = \gamma_{r^{f_n},b^{f_n}} = \gamma_{5,25},\ n \in \{0,1\}$

| $\text{arrivalBound}(s_1, \{f_0, f_1\}, \{\}) = \alpha_{s_1}^{\{f_0,f_1\}}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{\{f_0,f_1\}}$ | | $= \gamma_{10,50}$ | |
| $\alpha_{s_0}^{x\{f_0,f_1\}}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}\{f_0,f_1\}} = \beta_{s_0} \ominus \alpha_{s_0}^{x\{f_0,f_1\}} = \beta_{R_{s_0}^{\text{l.o.}\{f_0,f_1\}}, T_{s_0}^{\text{l.o.}\{f_0,f_1\}}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_1}^{\{f_0,f_1\}} = \alpha_{s_0}^{\{f_0,f_1\}} \oslash \beta_{s_0}^{\text{l.o.}\{f_0,f_1\}} = \gamma_{r_{s_1}^{\{f_0,f_1\}}, b_{s_1}^{\{f_0,f_1\}}}$ | $r_{s_1}^{\{f_0,f_1\}}$ | $= 10$ | |
| | $b_{s_1}^{\{f_0,f_1\}}$ | $\alpha_{s_0}^{\{f_0,f_1\}}(T_{s_0}^{\text{l.o.}\{f_0,f_1\}}) = 10 \cdot 20 + 50 = 250$ | |
| | $=$ | $= \gamma_{10,250}$ | |

| $\text{arrivalBound}(s_2, \{f_0, f_1\}, \{\}) = \alpha_{s_2}^{\{f_0,f_1\}}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_1}^{\{f_0,f_1\}}$ | | $= \gamma_{10,250}$ | |
| $\alpha_{s_1}^{x\{f_0,f_1\}}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_1}^{\text{l.o.}\{f_0,f_1\}} = \beta_{s_1} \ominus \alpha_{s_1}^{x\{f_0,f_1\}} = \beta_{R_{s_1}^{\text{l.o.}\{f_0,f_1\}}, T_{s_1}^{\text{l.o.}\{f_0,f_1\}}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_2}^{\{f_0,f_1\}} = \alpha_{s_1}^{\{f_0,f_1\}} \oslash \beta_{s_1}^{\text{l.o.}\{f_0,f_1\}} = \gamma_{r_{s_2}^{\{f_0,f_1\}}, b_{s_2}^{\{f_0,f_1\}}}$ | $r_{s_2}^{\{f_0,f_1\}}$ | $= 10$ | |
| | $b_{s_2}^{\{f_0,f_1\}}$ | $\alpha_{s_1}^{\{f_0,f_1\}}(T_{s_1}^{\text{l.o.}\{f_0,f_1\}}) = 10 \cdot 20 + 250 = 250$ | |
| | $=$ | $= \gamma_{10,450}$ | |

| $\text{arrivalBound}(s_1, \{f_0\}, \{f_1\}) = \alpha_{s_1}^{f_0}$ $= \text{arrivalBound}(s_1, \{f_1\}, \{f_0\}) = \alpha_{s_1}^{f_1}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{f_n}$ | | $= \gamma_{5,25}$ | |
| $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\text{l.o.}f_n}, T_{s_0}^{\text{l.o.}f_n}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\text{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$ | $r_{s_1}^{f_n}$ | $= 5$ | |
| | $b_{s_1}^{f_n}$ | $\alpha^{f_n}(T_{s_0}^{\text{l.o.}f_n}) = 5 \cdot 20 + 25 = 125$ | |
| | $=$ | $= \gamma_{5,125}$ | |

| $\text{arrivalBound}(s_2, \{f_0\}, \{f_1\}) = \alpha_{s_2}^{f_0}$ $= \text{arrivalBound}(s_2, \{f_1\}, \{f_0\}) = \alpha_{s_2}^{f_1}$ | FIFO_MUX | ARB_MUX |
|---|---|---|

| | | |
|---|---|---|
| $\alpha_{s_1}^{f_n}$ | | $= \gamma_{5,125}$ |
| $\alpha_{s_1}^{xf_n}$ | | $= \gamma_{0,0}$ |
| $\beta_{s_1}^{\text{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n} = \beta_{R_{s_1}^{\text{l.o.}f_n}, T_{s_1}^{\text{l.o.}f_n}}$ | | $= \beta_{20,20}$ |
| $\alpha_{s_2}^{f_n} = \alpha_{s_1}^{f_n} \oslash \beta_{s_1}^{\text{l.o.}f_n} = \gamma_{r_{s_2}^{f_n}, b_{s_2}^{f_n}}$ | $r_{s_2}^{f_n}$ | $= 5$ |
| | $b_{s_2}^{f_n}$ | $\alpha_{s_1}^{f_n}(T_{s_1}^{\text{l.o.}f_n}) = 5 \cdot 20 + 125 = 225$ |
| | $=$ | $= \gamma_{5,125}$ |

**Flows $f_n$, $n \in \{0, 1\}$**

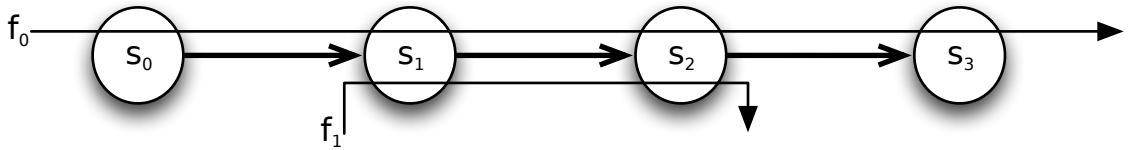
TFA results will be equal for all flows as they share the same path of servers.

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0} = \alpha_{s_0}^{f_0} + \alpha_{s_0}^{f_1}$ | $= \gamma_{10,50}$ | |
| | $D_{s_0}^{f_n}$ | $\beta_{s_0} = b_{s_0}$<br>$20 \cdot [t-20]^+ = 50$<br>$t = 22\frac{1}{2}$ | $\beta_{s_0} = \alpha_{s_0}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 50$<br>$t = 45$ |
| | $B_{s_0}^{f_n}$ | $\alpha_{s_0}(T_{s_0}) = 10 \cdot 20 + 50$<br>$= 250$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_1\}}$ | $= \gamma_{10,250}$ | |
| | $D_{s_1}^{f_n}$ | $\beta_{s_1} = b_{s_1}$<br>$20 \cdot [t-20]^+ = 250$<br>$t = 32\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 250$<br>$t = 65$ |
| | $B_{s_1}^{f_n}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 250$<br>$= 450$ | |
| $s_2$ | $\alpha_{s_2}^{f_0} = \alpha_{s_2}^{\{f_0,f_1\}}$ | $= \gamma_{10,450}$ | |
| | $D_{s_2}^{f_n}$ | $\beta_{s_2} = b_{s_2}$<br>$20 \cdot [t-20]^+ = 450$<br>$t = 42\frac{1}{2}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 450$<br>$t = 85$ |
| | $B_{s_2}^{f_n}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 450$<br>$= 650$ | |
| $D^{f_n}$ | | $\sum_{i=0}^{2} D_{s_i}^{f_n} = 97\frac{1}{2}$ | $\sum_{i=0}^{2} D_{s_i}^{f_n} = 195$ |
| $B^{f_n}$ | | $\max_{i=\{0,1,2\}} b_{s_i}^{f_n} = 650$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{xf_n}$ | | $= \gamma_{5,25}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\text{l.o.}f_n}, T_{s_0}^{\text{l.o.}f_n}}$ | $R_{s_0}^{\text{l.o.}f_n}$ | $= 15$ | |
| | | $T_{s_0}^{\text{l.o.}f_n}$ | $\beta_{s_0} = b_{s_0}^{xf_n}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 22\frac{1}{4}$ | $\beta_{s_0} = \alpha_{s_0}^{xf_n}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | | $=$ | $= \beta_{15,21\frac{1}{4}}$ | $= \beta_{15,28\frac{1}{3}}$ |
| $s_1$ | $\alpha_{s_1}^{xf_n}$ | | $= \gamma_{5,125}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n}$ | $R_{s_1}^{\text{l.o.}f_n}$ | $= 15$ | |
| | | $T_{s_1}^{\text{l.o.}f_n}$ | $\beta_{s_1} = b_{s_1}^{xf_n}$<br>$20 \cdot [t-20]^+ = 125$<br>$t = 26\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{xf_n}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 125$<br>$t = 35$ |
| | | $=$ | $= \beta_{15,26\frac{1}{4}}$ | $= \beta_{15,35}$ |
| $s_2$ | $\alpha_{s_2}^{xf_n}$ | | $= \gamma_{5,225}$ | |
| | $\beta_{s_2}^{\text{l.o.}f_n} = \beta_{s_2} \ominus \alpha_{s_2}^{xf_n}$ | $R_{s_2}^{\text{l.o.}f_n}$ | $= 15$ | |
| | | $T_{s_2}^{\text{l.o.}f_n}$ | $\beta_{s_2} = b_{s_2}^{xf_n}$<br>$20 \cdot [t-20]^+ = 225$<br>$t = 31\frac{1}{4}$ | $\beta_{s_2} = \alpha_{s_2}^{xf_n}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 225$<br>$t = 41\frac{2}{3}$ |
| | | $=$ | $= \beta_{15,31\frac{1}{4}}$ | $= \beta_{15,41\frac{2}{3}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n}, T_{\text{e2e}}^{\text{l.o.}f_n}}$ | | | $\bigotimes_{i=0}^{2} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{5,78\frac{3}{4}}$ | $\bigotimes_{i=0}^{2} \beta_{s_i}^{\text{l.o.}f_n} = \beta_{5,105}$ |
| $D^{f_n}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$15 \cdot [t - 78\frac{3}{4}]^+ = 25$<br>$t = 80\frac{5}{12}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$15 \cdot [t-105]^+ = 25$<br>$t = 106\frac{2}{3}$ |
| $B^{f_n}$ | | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 5 \cdot 78\frac{3}{4} + 25$<br>$= 418\frac{3}{4}$ | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 5 \cdot 105 + 25$<br>$= 550$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}f_n}$ | $= \gamma_{5,25}$ |
| | $\alpha_{s_0}^{xf_n}$ | $= \gamma_{5,25}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}f_n}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_1}^{xf_n}$ | $= \gamma_{5,75}$ |
| $s_2$ | $\alpha_{s_2}^{\bar{x}f_n}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_2}^{xf_n}$ | $= \gamma_{5,225}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n}, T_{\text{e2e}}^{\text{l.o.}f_n}}$ | $R_{\text{e2e}}^{\text{l.o.}f_n} = \bigwedge_{i\in\{0,1,2\}} \left(R_{s_i} - r_{s_i}^{xf_n}\right)$ | $= (20-5) \wedge (20-5) \wedge (20-5)$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_n} = \sum_{i\in\{0,1,2\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}f_n} + r_{s_i}^{xf_n} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_n}}\right)$ | $= 20 + \frac{25+5\cdot 20}{15} + 20 + \frac{0+5\cdot 20}{15} + 20 + \frac{0+5\cdot 20}{15}$<br>$= 81\frac{2}{3}$ |
| | $=$ | $= \beta_{15,81\frac{2}{3}}$ |
| $D^{f_n}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_n} = b^{f_n}$<br>$15 \cdot [t - 81\frac{2}{3}]^+ = 25$<br>$t = 83\frac{1}{3}$ |
| $B^{f_n}$ | | $\alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) = 5 \cdot 81\frac{2}{3} + 25$<br>$= 433\frac{1}{3}$ |

**Tandem_1SC_2Flows_1AC_2Paths_v2**




- $\beta_{s_0} = \beta_{s_1} = \beta_{s_2} = \beta_{s_3} = \beta_{R_{s_i},T_{s_i}} = \beta_{20,20}$, $i \in \{0,1\}$
- $\mathcal{F} = \{f_0, f_1\}$

$\alpha^{f_0} = \alpha^{f_1} = \gamma_{r^{fn},b^{fn}} = \gamma_{5,25}$, $n \in \{0,1\}$

| $\text{arrivalBound}(s_1, \{f_0\}, \mathcal{G}),\ \mathcal{G} \in \mathcal{P}(\mathcal{F}) = \alpha_{s_1}^{f_0}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_0}^{f_0}$ | | $= \gamma_{5,25}$ | |
| $\alpha_{s_0}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{R_{s_0}^{\text{l.o.}f_0}, T_{s_0}^{\text{l.o.}f_0}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_1}^{f_0} = \alpha_{s_0}^{f_0} \oslash \beta_{s_0}^{\text{l.o.}f_0} = \gamma_{r_{s_1}^{f_0}, b_{s_1}^{f_0}}$ | $r_{s_1}^{f_0}$ | $= 10$ | |
| | $b_{s_1}^{f_0}$ | $\alpha_{s_0}^{f_0}(T_{s_0}^{\text{l.o.}f_0}) = 5 \cdot 20 + 25 = 125$ | |
| | $=$ | $= \gamma_{5,125}$ | |

| $\text{arrivalBound}(s_2, \{f_0\}, \{f_0\}) = \alpha_{s_2}^{f_0}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_1}^{f_0}$ | | $= \gamma_{5,125}$ | |
| $\alpha_{s_1}^{x(f_0)}$ | | $= \gamma_{5,25}$ | |
| $\beta_{s_1}^{\text{l.o.}f_0} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_0)}$ | $R_{s_1}^{\text{l.o.}f_0}$ | $= 15$ | |
| | $T_{s_1}^{\text{l.o.}f_0}$ | $\beta_{s_1} = b_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | $=$ | $=\beta_{15,21\frac{1}{4}}$ | $=\beta_{15,28\frac{1}{3}}$ |
| $\alpha_{s_2}^{f_0} = \alpha_{s_1}^{f_0} \oslash \beta_{s_1}^{\text{l.o.}f_0} = \gamma_{r_{s_2}^{f_0}, b_{s_2}^{f_0}}$ | $r_{s_2}^{f_0}$ | $= 5$ | |
| | $b_{s_2}^{f_0}$ | $\alpha_{s_1}^{f_0}(T_{s_1}^{\text{l.o.}f_0}) = 5 \cdot 21\frac{1}{4} + 125 = 231\frac{1}{4}$ | $\alpha_{s_1}^{f_0}(T_{s_1}^{\text{l.o.}f_0}) = 5 \cdot 28\frac{1}{3} + 125 = 266\frac{2}{3}$ |
| | $=$ | $= \gamma_{5,231\frac{1}{4}}$ | $= \gamma_{5,266\frac{2}{3}}$ |

| $\text{arrivalBound}(s_2, \{f_1\}, \{f_0\}) = \alpha_{s_2}^{f_1}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_1}^{f_1}$ | | $= \gamma_{5,25}$ | |
| $\alpha_{s_1}^{x(f_1)}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_1}^{\text{l.o.}f_1} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_1)} = \beta_{R_{s_1}^{\text{l.o.}f_1}, T_{s_1}^{\text{l.o.}f_1}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_2}^{f_1} = \alpha_{s_1}^{f_1} \oslash \beta_{s_1}^{\text{l.o.}f_1} = \gamma_{r_{s_1}^{f_1}, b_{s_1}^{f_1}}$ | $r_{s_2}^{f_1}$ | $= 10$ | |
| | $b_{s_2}^{f_1}$ | $\alpha_{s_1}^{f_1}(T_{s_1}^{\text{l.o.}f_1}) = 5 \cdot 20 + 25 = 125$ | |
| | $=$ | $= \gamma_{5,125}$ | |

**PBOO-AB:**

| $\text{arrivalBound}(s_3, \{f_0\}, \{\}) = \alpha^{f_0}_{s_3}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha^{f_0}_{s_2}$ | | $= \gamma_{5,231\frac{1}{4}}$ | $= \gamma_{5,266\frac{2}{3}}$ |
| $\alpha^{x(f_0)}_{s_2}$ | | $= \gamma_{5,125}$ | |
| $\beta^{\text{l.o.}f_0}_{s_2} = \beta_{s_2} \ominus \alpha^{x(f_0)}_{s_2}$ | $R^{\text{l.o.}f_0}_{s_2}$ | $= 15$ | |
| | $T^{\text{l.o.}f_0}_{s_2}$ | $\beta_{s_2} = b^{x(f_0)}_{s_2}$<br>$20 \cdot [t-20]^+ = 156\frac{1}{4}$<br>$t = 27\frac{13}{16}$ | $\beta_{s_2} = \alpha^{x(f_0)}_{s_2}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 200$<br>$t = 40$ |
| | $=$ | $=\beta_{15,27\frac{13}{16}}$ | $=\beta_{15,40}$ |
| $\alpha^{f_0}_{s_3} = \alpha^{f_0}_{s_2} \oslash \beta^{\text{l.o.}f_0}_{s_2} = \gamma_{r^{f_1}_{s_3}, b^{f_1}_{s_3}}$ | $r^{f_0}_{s_3}$ | $= 5$ | |
| | $b^{f_0}_{s_3}$ | $\alpha^{f_0}_{s_2}(T^{\text{l.o.}f_0}_{s_2}) = 370\frac{5}{16}$ | $\alpha^{f_0}_{s_2}(T^{\text{l.o.}f_0}_{s_2}) = 466\frac{2}{3}$ |
| | $=$ | $= \gamma_{5,370\frac{5}{16}}$ | $= \gamma_{5,466\frac{2}{3}}$ |

**PMOO-AB, ARB_MUX:**

$$\alpha^{f_0}_{s_3} = \alpha^{f_0} \oslash \beta^{\mathbf{l.o.}f_0}_{\langle s_0, s_2 \rangle}$$

Note, that we use a simplified notation here due to the use of rate-latencies and token-buckets as well as the lack of demultiplexing on the analyzed path.

$$\begin{aligned}
\beta^{\mathbf{l.o.}f_0}_{\langle s_0, s_2 \rangle} &= \beta_{s_0} \otimes \left( (\beta_{s_1} \otimes \beta_{s_2}) \ominus \alpha^{f_1} \right) \\
&= \beta_{20,20} \otimes \left( (\beta_{20,20} \otimes \beta_{20,20}) \ominus \gamma_{5,25} \right) \\
&= \beta_{20,20} \otimes \left( \beta_{20,40} \ominus \gamma_{5,25} \right) \\
&= \beta_{20,20} \otimes \beta_{15,55} \\
&= \beta_{15,75}
\end{aligned}$$

$$\begin{aligned}
\alpha^{f_0}_{s_3} &= \alpha^{f_0} \oslash \beta^{\mathbf{l.o.}f_0}_{\langle s_0, s_2 \rangle} \\
&= \gamma_{5,25} \oslash \beta_{15,75} \\
&= \gamma_{5,400}
\end{aligned}$$

| $\text{arrivalBound}(s_2, \{f_0, f_1\}, \{\}) = \alpha_{s_2}^{\{f_0,f_1\}}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_1}^{\{f_0,f_1\}}$ | | $= \gamma_{10,150}$ | |
| $\alpha_{s_1}^{x\{f_0,f_1\}}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_1}^{\text{l.o.}\{f_0,f_1\}} = \beta_{s_1} \ominus \alpha_{s_1}^{x\{f_0,f_1\}} = \beta_{R_{s_1}^{\text{l.o.}\{f_0,f_1\}}, T_{s_1}^{\text{l.o.}\{f_0,f_1\}}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_2}^{\{f_0,f_1\}} = \alpha_{s_1}^{\{f_0,f_1\}} \oslash \beta_{s_1}^{\text{l.o.}\{f_0,f_1\}} = \gamma_{r_{s_2}^{\{f_0,f_1\}}, b_{s_2}^{\{f_0,f_1\}}}$ | $r_{s_2}^{\{f_0,f_1\}}$ | $= 10$ | |
| | $b_{s_2}^{\{f_0,f_1\}}$ | $\alpha_{s_1}^{\{f_0,f_1\}}(T_{s_1}^{\text{l.o.}\{f_0,f_1\}}) = 10 \cdot 20 + 150 = 350$ | |
| | $=$ | $= \gamma_{10,350}$ | |

| $\text{arrivalBound}(s_2, \{f_0\}, \{f_1\}) = \alpha_{s_2}^{f_0}$ | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $\alpha_{s_1}^{f_0}$ | | $= \gamma_{5,125}$ | |
| $\alpha_{s_1}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| $\beta_{s_1}^{\text{l.o.}f_0} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_0)} = \beta_{R_{s_1}^{\text{l.o.}f_0}, T_{s_1}^{\text{l.o.}f_0}}$ | | $= \beta_{20,20}$ | |
| $\alpha_{s_2}^{f_0} = \alpha_{s_1}^{f_0} \oslash \beta_{s_1}^{\text{l.o.}f_0} = \gamma_{r_{s_1}^{f_0}, b_{s_1}^{f_0}}$ | $r_{s_2}^{f_0}$ | $= 10$ | |
| | $b_{s_2}^{f_0}$ | $\alpha_{s_1}^{f_0}(T_{s_1}^{\text{l.o.}f_0}) = 5 \cdot 20 + 125 = 225$ | |
| | $=$ | $= \gamma_{5,225}$ | |

**Flow $f_0$**

**PBOO-AB:**

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_0$ | $\alpha_{s_0}$ | $= \gamma_{5,25}$ | |
| | $D_{s_0}^{f_0}$ | $\beta_{s_0} = b_{s_0}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | FIFO per microflow<br>$\beta_{s_0} = b_{s_0}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ |
| | $B_{s_0}^{f_0}$ | $\alpha_{s_0}(T_{s_0}) = 5 \cdot 20 + 25$<br>$= 125$ | |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{f_0} + \alpha_{s_1}^{f_1}$ | $= \gamma_{5,125} + \gamma_{5,25} = \gamma_{10,150}$ | |
| | $D_{s_1}^{f_0}$ | $\beta_{s_1} = b_{s_1}$<br>$20 \cdot [t-20]^+ = 150$<br>$t = 27\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 150$<br>$t = 55$ |
| | $B_{s_1}^{f_0}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 150$<br>$= 350$ | |
| $s_2$ | $\alpha_{s_2} = \alpha_{s_2}^{\{f_0,f_1\}}$ | $= \gamma_{10,350}$ | |
| | $D_{s_2}^{f_0}$ | $\beta_{s_2} = b_{s_2}$<br>$20 \cdot [t-20]^+ = 350$<br>$t = 37\frac{1}{2}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 350$<br>$t = 75$ |
| | $B_{s_2}^{f_0}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 350$<br>$= 550$ | |
| $s_3$ | $\alpha_{s_3} = \alpha_{s_3}^{f_0}$ | $= \gamma_{5,370\frac{5}{16}}$ | $= \gamma_{5,466\frac{2}{3}}$ |
| | $D_{s_3}^{f_0}$ | $\beta_{s_3} = b_{s_3}$<br>$20 \cdot [t-20]^+ = 370\frac{5}{16}$<br>$t = 38\frac{33}{64}$ | FIFO per micro flow<br>$\beta_{s_3} = b_{s_3}$<br>$20 \cdot [t-20]^+ = 466\frac{2}{3}$<br>$t = 43\frac{1}{3}$ |
| | $B_{s_3}^{f_0}$ | $\alpha_{s_3}(T_{s_3}) = 5 \cdot 20 + 370\frac{5}{16}$<br>$= 470\frac{5}{16}$ | $\alpha_{s_3}(T_{s_3}) = 5 \cdot 20 + 466\frac{2}{3}$<br>$= 566\frac{2}{3}$ |
| $D^{f_0}$ | | $\sum_{i=0}^{3} D_{s_i}^{f_0} = 124\frac{49}{64}$ | $\sum_{i=0}^{3} D_{s_i}^{f_0} = 194\frac{7}{12}$ |
| $B^{f_0}$ | | $\max_{i=0}^{3} b_{s_i}^{f_0} = 550$ | $\max_{i=0}^{3} b_{s_i}^{f_0} = 566\frac{2}{3}$ |

**PMOO-AB:**

| TFA | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}$ | $= \gamma_{5,25}$ |
| | $D_{s_0}^{f_0}$ | FIFO per microflow<br>$\beta_{s_0} = b_{s_0}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ |
| | $B_{s_0}^{f_0}$ | $\alpha_{s_0}(T_{s_0}) = 125$ |
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{f_0} + \alpha_{s_1}^{f_1}$ | $= \gamma_{5,125} + \gamma_{5,25} = \gamma_{10,150}$ |
| | $D_{s_1}^{f_0}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 150$<br>$t = 55$ |
| | $B_{s_1}^{f_0}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 150$<br>$= 350$ |
| $s_2$ | $\alpha_{s_2} = \alpha_{s_2}^{\{f_0,f_1\}}$ | $= \gamma_{10,350}$ |
| | $D_{s_2}^{f_0}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 350$<br>$t = 75$ |
| | $B_{s_2}^{f_0}$ | $\alpha_{s_2}(T_{s_2}) = 550$ |
| $s_3$ | $\alpha_{s_3} = \alpha_{s_3}^{f_0}$ | $= \gamma_{5,400}$ |
| | $D_{s_3}^{f_0}$ | FIFO per micro flow<br>$\beta_{s_3} = b_{s_3}$<br>$20 \cdot [t-20]^+ = 400$<br>$t = 40$ |
| | $B_{s_3}^{f_0}$ | $\alpha_{s_3}(T_{s_3}) = 5 \cdot 20 + 400$<br>$= 500$ |
| $D^{f_0}$ | | $\sum_{i=0}^{3} D_{s_i}^{f_0} = 191\frac{1}{4}$ |
| $B^{f_0}$ | | $\max_{i=0}^{3} b_{s_i}^{f_0} = 550$ |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_0$ | $\alpha_{s_0}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| | $\beta_{s_0}^{\text{l.o.}f_0}$ | | $= \beta_{20,20}$ | |
| $s_1$ | $\alpha_{s_1}^{x(f_0)}$ | | $= \gamma_{5,25}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_0} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_0)}$ | $R_{s_1}^{\text{l.o.}f_0}$ | $= 15$ | |
| | | $T_{s_1}^{\text{l.o.}f_0}$ | $\beta_{s_1} = b_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 25$<br>$t = 21\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 25$<br>$t = 28\frac{1}{3}$ |
| | | $=$ | $= \beta_{15,21\frac{1}{4}}$ | $= \beta_{15,28\frac{1}{3}}$ |
| $s_2$ | $\alpha_{s_2}^{x(f_0)}$ | | $= \gamma_{5,125}$ | |
| | $\beta_{s_2}^{\text{l.o.}f_0} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_0)}$ | $R_{s_2}^{\text{l.o.}f_0}$ | $= 15$ | |
| | | $T_{s_2}^{\text{l.o.}f_0}$ | $\beta_{s_2} = b_{s_2}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 125$<br>$t = 26\frac{1}{4}$ | $\beta_{s_2} = \alpha_{s_2}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 125$<br>$t = 35$ |
| | | $=$ | $= \beta_{15,26\frac{1}{4}}$ | $= \beta_{15,35}$ |
| $s_3$ | $\alpha_{s_3}^{x(f_0)}$ | | $= \gamma_{0,0}$ | |
| | $\beta_{s_3}^{\text{l.o.}f_0} = \beta_{s_3} \ominus \alpha_{s_3}^{x(f_0)}$ | | $= \beta_{20,20}$ | |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | | | $\bigotimes_{i=0}^{3} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,87\frac{1}{2}}$ | $\bigotimes_{i=0}^{3} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,103\frac{1}{3}}$ |
| $D^{f_0}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t - 87\frac{1}{2}]^+ = 25$<br>$t = 89\frac{1}{6}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t - 103\frac{1}{3}]^+ = 25$<br>$t = 105$ |
| $B^{f_0}$ | | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 87\frac{1}{2} + 25$<br>$= 462\frac{1}{2}$ | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 103\frac{1}{3} + 25$<br>$= 541\frac{2}{3}$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_0$ | $\alpha_{s_0}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_0}^{x(f_0)}$ | $= \gamma_{0,0}$ |
| $s_1$ | $\alpha_{s_1}^{\bar{x}(f_0)}$ | $= \gamma_{5,25}$ |
| | $\alpha_{s_1}^{x(f_0)}$ | $= \gamma_{5,25}$ |
| $s_2$ | $\alpha_{s_2}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_2}^{x(f_0)}$ | $= \gamma_{5,125}$ |
| $s_3$ | $\alpha_{s_3}^{\bar{x}(f_0)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_3}^{x(f_0)}$ | $= \gamma_{0,0}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$ | $R_{\text{e2e}}^{\text{l.o.}f_0} = \bigwedge_{i\in\{0,1,2,3\}} \left(R_{s_i} - r_{s_i}^{x(f_0)}\right)$ | $= (20-0) \wedge (20-5) \wedge (20-5) \wedge (20-0)$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_0} = \sum_{i\in\{0,1,2,3\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_0)} + r_{s_i}^{x(f_0)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_0}}\right)$ | $= 20 + \frac{0+0\cdot 20}{15} + 20 + \frac{25+5\cdot 20}{15} + 20 + \frac{0+5\cdot 20}{15} + 20 + \frac{0+0\cdot 20}{15}$<br>$= 95$ |
| | $=$ | $= \beta_{15,95}$ |
| $D^{f_0}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_0} = b^{f_0}$<br>$15 \cdot [t-95]^+ = 25$<br>$t = 96\frac{2}{3}$ |
| $B^{f_0}$ | | $\alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = 5 \cdot 95 + 25$<br>$= 500$ |

**Flow $f_1$**

| TFA | | FIFO_MUX | ARB_MUX |
|---|---|---|---|
| $s_1$ | $\alpha_{s_1} = \alpha_{s_1}^{f_0} + \alpha_{s_1}^{f_1}$ | $= \gamma_{5,25} + \gamma_{5,125} = \gamma_{10,150}$ | |
| | $D_{s_1}^{f_1}$ | $\beta_{s_1} = b_{s_1}$<br>$20 \cdot [t-20]^+ = 150$<br>$t = 27\frac{1}{2}$ | $\beta_{s_1} = \alpha_{s_1}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 150$<br>$t = 55$ |
| | $B_{s_1}^{f_1}$ | $\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 150$<br>$= 350$ | |
| $s_2$ | $\alpha_{s_2} = \alpha_{s_2}^{\{f_0,f_1\}}$ | $= \gamma_{10,350}$ | |
| | $D_{s_2}^{f_1}$ | $\beta_{s_2} = b_{s_2}$<br>$20 \cdot [t-20]^+ = 350$<br>$t = 37\frac{1}{2}$ | $\beta_{s_2} = \alpha_{s_2}$<br>$20 \cdot [t-20]^+ = 10 \cdot t + 350$<br>$t = 75$ |
| | $B_{s_2}^{f_1}$ | $\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 350$<br>$= 550$ | |
| $D^{f_1}$ | | $\sum_{i=1}^{2} D_{s_i}^{f_1} = 65$ | $\sum_{i=1}^{2} D_{s_i}^{f_1} = 130$ |
| $B^{f_1}$ | | $\max_{i=1}^{2} b_{s_i}^{f_1} = 550$ | |

| SFA | | | FIFO_MUX | ARB_MUX |
|---|---|---|---|---|
| $s_1$ | $\alpha_{s_1}^{x(f_1)}$ | | $= \gamma_{5,125}$ | |
| | $\beta_{s_1}^{\text{l.o.}f_1} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_1)}$ | $R_{s_1}^{\text{l.o.}f_1}$ | $= 15$ | |
| | | $T_{s_1}^{\text{l.o.}f_1}$ | $\beta_{s_1} = b_{s_1}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 125$<br>$t = 26\frac{1}{4}$ | $\beta_{s_1} = \alpha_{s_1}^{x(f_0)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 125$<br>$t = 35$ |
| | | $=$ | $= \beta_{15,26\frac{1}{4}}$ | $= \beta_{15,35}$ |
| $s_2$ | $\alpha_{s_2}^{x(f_1)}$ | | $= \gamma_{5,225}$ | |
| | $\beta_{s_2}^{\text{l.o.}f_1} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_1)}$ | $R_{s_2}^{\text{l.o.}f_1}$ | $= 15$ | |
| | | $T_{s_2}^{\text{l.o.}f_1}$ | $\beta_{s_2} = b_{s_2}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 225$<br>$t = 31\frac{1}{4}$ | $\beta_{s_2} = \alpha_{s_2}^{x(f_1)}$<br>$20 \cdot [t-20]^+ = 5 \cdot t + 225$<br>$t = 41\frac{2}{3}$ |
| | | $=$ | $= \beta_{15,31\frac{1}{4}}$ | $= \beta_{15,41\frac{2}{3}}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_1}, T_{\text{e2e}}^{\text{l.o.}f_1}}$ | | | $\bigotimes_{i=1}^{2} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,57\frac{1}{2}}$ | $\bigotimes_{i=1}^{2} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,76\frac{2}{3}}$ |
| $D^{f_1}$ | | | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t-57\frac{1}{2}]^+ = 25$<br>$t = 59\frac{1}{6}$ | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t-76\frac{2}{3}]^+ = 25$<br>$t = 78\frac{1}{3}$ |
| $B^{f_1}$ | | | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 57\frac{1}{2} + 25$<br>$= 312\frac{1}{2}$ | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 76\frac{2}{3} + 25$<br>$= 408\frac{1}{3}$ |

| PMOO | | ARB_MUX |
|---|---|---|
| $s_1$ | $\alpha_{s_1}^{\bar{x}(f_1)}$ | $= \gamma_{5,125}$ |
| | $\alpha_{s_1}^{x(f_1)}$ | $= \gamma_{5,125}$ |
| $s_2$ | $\alpha_{s_2}^{\bar{x}(f_1)}$ | $= \gamma_{0,0}$ |
| | $\alpha_{s_2}^{x(f_1)}$ | $= \gamma_{5,225}$ |
| $\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_1}, T_{\text{e2e}}^{\text{l.o.}f_1}}$ | $R_{\text{e2e}}^{\text{l.o.}f_1} = \bigwedge_{i\in\{1,2\}} \left(R_{s_i} - r_{s_i}^{x(f_1)}\right)$ | $= (20-5) \wedge (20-5)$<br>$= 15$ |
| | $T_{\text{e2e}}^{\text{l.o.}f_1} = \sum_{i\in\{1,2\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_1)} + r_{s_i}^{x(f_1)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_1}}\right)$ | $= 20 + \frac{125 + 5\cdot 20}{15} + 20 + \frac{0 + 5\cdot 20}{15}$<br>$= 61\frac{2}{3}$ |
| | $=$ | $= \beta_{15,81\frac{2}{3}}$ |
| $D^{f_1}$ | | $\beta_{\text{e2e}}^{\text{l.o.}f_1} = b^{f_1}$<br>$15 \cdot [t - 61\frac{2}{3}]^+ = 25$<br>$t = 63\frac{1}{3}$ |
| $B^{f_1}$ | | $\alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) = 5 \cdot 61\frac{2}{3} + 25$<br>$= 333\frac{1}{3}$ |