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.

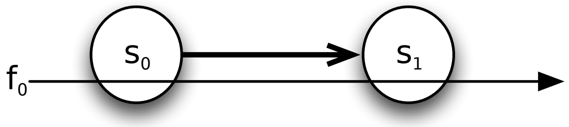
Changelog:

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



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

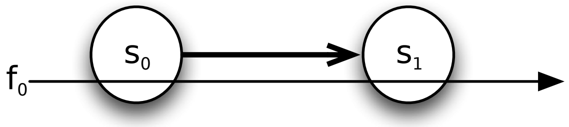
<table>
<tr><td colspan="2">$\text{arrivalBound}(s_1, \{f_0\}, \mathcal{G}), \mathcal{G} \in \mathcal{P}(\mathcal{F}) = \alpha_{s_1}^{f_0}$</td><td>FIFO_MUX</td><td>ARB_MUX</td></tr>
<tr><td colspan="2">$\alpha_{s_0}^{f_0}$</td><td colspan="2">$= \gamma_{5,25}$</td></tr>
<tr><td colspan="2">$\alpha_{s_0}^{x(f_0)}$</td><td colspan="2">$= \gamma_{0,0}$</td></tr>
<tr><td colspan="2">$\beta_{s_0}^{\text{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{R_{s_0}^{\text{l.o.}f_0}, T_{s_0}^{\text{l.o.}f_0}}$</td><td colspan="2">$= \beta_{10,10}$</td></tr>
<tr><td rowspan="3">$\alpha_{s_1}^{f_0} = \alpha^{f_0} \oslash \beta_{s_0}^{\text{l.o.}f_0} = \gamma_{r_{s_1}^{f_0}, b_{s_1}^{f_0}}$</td><td>$r_{s_1}^{f_0}$</td><td colspan="2">$= 5$</td></tr>
<tr><td>$b_{s_1}^{f_0}$</td><td colspan="2">$\alpha^{f_0}(T_{s_0}^{\text{l.o.}f_0}) = 5 \cdot 10 + 25 = 75$</td></tr>
<tr><td>$=$</td><td colspan="2">$= \gamma_{5,75}$</td></tr>
</table>

<table>
<tr><th colspan="2">TFA</th><th>FIFO_MUX</th><th>ARB_MUX</th></tr>
<tr><td rowspan="3">s_0</td><td>$\alpha_{s_0} = \alpha^{f_0}$</td><td colspan="2">$= \gamma_{5,25}$</td></tr>
<tr><td>$D^{f_0}_{s_0}$</td><td>$$\begin{aligned} \beta_{s_0} = &\ b_{s_0} \\ 10 \cdot [t-10]^+ = &\ 25 \\ t = &\ 12\frac{1}{2} \end{aligned}$$</td><td>FIFO per mico flow $$\begin{aligned} \beta_{s_0} = &\ b_{s_0} \\ 10 \cdot [t-10]^+ = &\ 25 \\ t = &\ 12\frac{1}{2} \end{aligned}$$</td></tr>
<tr><td>$B^{f_0}_{s_0}$</td><td colspan="2">$$\begin{aligned} \alpha_{s_0}(T_{s_0}) = &\ 5 \cdot 10 + 25 \\ = &\ 75 \end{aligned}$$</td></tr>
<tr><td rowspan="3">s_1</td><td>$\alpha_{s_1} = \alpha^{f_0}_{s_1}$</td><td colspan="2">$= \gamma_{5,75}$</td></tr>
<tr><td>$D^{f_0}_{s_1}$</td><td>$$\begin{aligned} \beta_{s_1} = &\ b_{s_1} \\ 10 \cdot [t-10]^+ = &\ 75 \\ t = &\ 17\frac{1}{2} \end{aligned}$$</td><td>FIFO per micro flow $$\begin{aligned} \beta_{s_1} = &\ b_{s_1} \\ 10 \cdot [t-10]^+ = &\ 75 \\ t = &\ 17\frac{1}{2} \end{aligned}$$</td></tr>
<tr><td>$B^{f_0}_{s_1}$</td><td colspan="2">$$\begin{aligned} \alpha_{s_1}(T_{s_1}) = &\ 5 \cdot 10 + 75 \\ = &\ 125 \end{aligned}$$</td></tr>
<tr><td colspan="2">D^{f_0}</td><td colspan="2">$\sum_{i=0}^{1} D^{f_0}_{s_i} = 30$</td></tr>
<tr><td colspan="2">B^{f_0}</td><td colspan="2">$\max_{i=\{0,1\}} b^{f_0}_{s_i} = 125$</td></tr>
</table>

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}		$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_0} &= b^{f_0} \\ 10 \cdot [t-20]^+ &= 25 \\ t &= 22\frac{1}{2} \end{aligned}$
B^{f_0}		$\begin{aligned} \alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) &= 5 \cdot 20 + 25 \\ &= 125 \end{aligned}$

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

Tandem_2SCs_1Flow



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

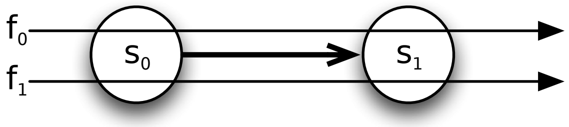
arrivalBound$(s_1, \{f_0\}, \mathcal{G})$, $\mathcal{G} \in \mathcal{P}(\mathcal{F}) = \alpha_{s_1}^{f_0}$		FIFO_MUX	ARB_MUX
$\alpha_{s_0}^{f_0}$		$= \gamma_{5,25}$	
$\alpha_{s_0}^{x(f_0)}$		$= \gamma_{0,0}$	
$\beta_{s_0}^{\mathrm{l.o.}f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{R_{s_0}^{\mathrm{l.o.}f_0},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

<table>
<tr><td colspan="2">TFA</td><td>FIFO_MUX</td><td>ARB_MUX</td></tr>
<tr><td rowspan="3">s_0</td><td>$\alpha_{s_0} = \alpha^{f_0}$</td><td colspan="2">$= \gamma_{5,25}$</td></tr>
<tr><td>$D^{f_0}_{s_0}$</td><td>$$\begin{aligned} \beta_{s_0} &= b_{s_0} \\ 10 \cdot [t-10]^+ &= 25 \\ t &= 12\frac{1}{2} \end{aligned}$$</td><td>FIFO per micro flow $$\begin{aligned} \beta_{s_0} &= b_{s_0} \\ 10 \cdot [t-10]^+ &= 25 \\ t &= 12\frac{1}{2} \end{aligned}$$</td></tr>
<tr><td>$B^{f_0}_{s_0}$</td><td colspan="2">$$\begin{aligned} \alpha_{s_0}(T_{s_0}) &= 5 \cdot 10 + 25 \\ &= 75 \end{aligned}$$</td></tr>
<tr><td rowspan="3">s_1</td><td>$\alpha_{s_1} = \alpha^{f_0}_{s_1}$</td><td colspan="2">$= \gamma_{5,75}$</td></tr>
<tr><td>$D^{f_0}_{s_1}$</td><td>$$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 6 \cdot [t-6]^+ &= 75 \\ t &= 18\frac{1}{2} \end{aligned}$$</td><td>FIFO per micro flow $$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 6 \cdot [t-6]^+ &= 75 \\ t &= 18\frac{1}{2} \end{aligned}$$</td></tr>
<tr><td>$B^{f_0}_{s_1}$</td><td colspan="2">$$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 5 \cdot 6 + 75 \\ &= 105 \end{aligned}$$</td></tr>
<tr><td colspan="2">D^{f_0}</td><td colspan="2">$\sum_{i=0}^{1} D^{f_0}_{s_i} = 31$</td></tr>
<tr><td colspan="2">B^{f_0}</td><td colspan="2">$\max_{i=\{0,1\}} b^{f_0}_{s_i} = 105$</td></tr>
</table>

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}		$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_0} = &\quad b^{f_0} \\ 6 \cdot [t-16]^+ = &\quad 25 \\ t = &\quad 20\frac{1}{6} \end{aligned}$	
B^{f_0}		$\begin{aligned} \alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) = &\quad 5 \cdot 16 + 25 \\ = &\quad 105 \end{aligned}$	

<table>
<tr><th colspan="2">PMOO</th><th>ARB_MUX</th></tr>
<tr><td rowspan="2">s_0</td><td>$\alpha_{s_0}^{\bar{x}(f_0)}$</td><td>$= \gamma_{0,0}$</td></tr>
<tr><td>$\alpha_{s_0}^{x(f_0)}$</td><td>$= \gamma_{0,0}$</td></tr>
<tr><td rowspan="2">s_1</td><td>$\alpha_{s_1}^{\bar{x}(f_0)}$</td><td>$= \gamma_{0,0}$</td></tr>
<tr><td>$\alpha_{s_0}^{x(f_0)}$</td><td>$= \gamma_{0,0}$</td></tr>
<tr><td rowspan="3">$\beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_0} = \beta_{R_{\mathrm{e2e}}^{\mathrm{l.o.}f_0}, T_{\mathrm{e2e}}^{\mathrm{l.o.}f_0}}$</td><td>$R_{\mathrm{e2e}}^{\mathrm{l.o.}f_0} = \bigwedge_{i\in\{0,1\}} \left(R_{s_i} - r_{s_i}^{x(f_0)} \right)$</td><td>$= (10-0) \wedge (6-0)$
$= 6$</td></tr>
<tr><td>$T_{\mathrm{e2e}}^{\mathrm{l.o.}f_0} = \sum_{i\in\{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_0)} + r_{s_i}^{x(f_0)} \cdot T_{s_i}}{R_{\mathrm{e2e}}^{\mathrm{l.o.}f_0}} \right)$</td><td>$= 10 + \frac{0 + 0 \cdot 10}{6} + 6 + \frac{0 + 0 \cdot 6}{6}$
$= 16$</td></tr>
<tr><td>$=$</td><td>$= \beta_{6,16}$</td></tr>
<tr><td colspan="2">D^{f_0}</td><td>$\beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_0} = b^{f_0}$
$6 \cdot [t-16]^+ = 25$
$t = 20\frac{1}{6}$</td></tr>
<tr><td colspan="2">B^{f_0}</td><td>$\alpha^{f_0}(T_{\mathrm{e2e}}^{\mathrm{l.o.}f_0}) = 5 \cdot 16 + 25$
$= 105$</td></tr>
</table>

Tandem_1SC_2Flows_1AC_1Path



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

$\mathrm{arrivalBound}(s_1, \{f_0\}, \{f_1\}) = \alpha_{s_1}^{f_0}$ $= \mathrm{arrivalBound}(s_1, \{f_1\}, \{f_0\}) = \alpha_{s_1}^{f_1}$		FIFO_MUX	ARB_MUX
$\alpha_{s_0}^{f_n}$		$= \gamma_{5,25}$	
$\alpha_{s_0}^{xf_n}$		$= \gamma_{0,0}$	
$\beta_{s_0}^{\mathrm{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\mathrm{l.o.}f_n}, T_{s_0}^{\mathrm{l.o.}f_n}}$		$= \beta_{10,10}$	
$\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\mathrm{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$	$r_{s_1}^{f_n}$	$= 5$	
	$b_{s_1}^{f_n}$	$\alpha^{f_0}(T_{s_0}^{\mathrm{l.o.}f_0}) = 5 \cdot 10 + 25 = 75$	
	$=$	$= \gamma_{5,75}$	

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

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	$\alpha_{s_0} = \alpha^{f_0} + \alpha^{f_1}$	$= \gamma_{10,50}$	
	$D_{s_0}^{f_n}$	$\begin{aligned} \beta_{s_0} &= b_{s_0} \\ 10 \cdot [t-10]^+ &= 50 \\ t &= 15 \end{aligned}$	$\begin{aligned} \beta_{s_0} &= \alpha_{s_0} \\ 10 \cdot [t-10]^+ &= 10 \cdot t + 50 \\ 0 \cdot t &= 150 \\ \Rightarrow \quad D_{s_0}^{f_n} &= \infty \end{aligned}$
	$B_{s_0}^{f_n}$	$\begin{aligned} \alpha_{s_0}(T_{s_0}) &= 10 \cdot 10 + 50 \\ &= 150 \end{aligned}$	
s_1	$\alpha_{s_1} = \alpha_{s_1}^{\{f_0, f_1\}}$	$= \gamma_{10,150}$	
	$D_{s_1}^{f_n}$	$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 10 \cdot [t-10]^+ &= 150 \\ t &= 25 \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1} \\ 10 \cdot [t-10]^+ &= 10 \cdot t + 150 \\ 0 \cdot t &= 250 \\ \Rightarrow \quad D_{s_1}^{f_n} &= \infty \end{aligned}$
	$B_{s_1}^{f_n}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 10 \cdot 10 + 150 \\ &= 250 \end{aligned}$	
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	$\alpha_{s_0}^{xf_n}$		$= \gamma_{5,25}$	
	$\beta_{s_0}^{\mathrm{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_n)}$	$R_{s_0}^{\mathrm{l.o.}f_n}$	$= 5$	
		$T_{s_0}^{\mathrm{l.o.}f_n}$	$\begin{aligned} \beta_{s_0} &= b_{s_0}^{xf_n} \\ 10 \cdot [t-10]^+ &= 25 \\ t &= 12\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_0} &= \alpha_{s_0}^{xf_n} \\ 10 \cdot [t-10]^+ &= 5 \cdot t + 25 \\ t &= 25 \end{aligned}$
		$=$	$= \beta_{5,12\frac{1}{2}}$	$= \beta_{5,25}$
s_1	$\alpha_{s_1}^{xf_n}$		$= \gamma_{5,75}$	
	$\beta_{s_1}^{\mathrm{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n}$	$R_{s_1}^{\mathrm{l.o.}f_n}$	$= 5$	
		$T_{s_1}^{\mathrm{l.o.}f_n}$	$\begin{aligned} \beta_{s_1} &= b_{s_1}^{xf_n} \\ 10 \cdot [t-10]^+ &= 75 \\ t &= 17\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1}^{xf_n} \\ 10 \cdot [t-10]^+ &= 5 \cdot t + 75 \\ t &= 35 \end{aligned}$
		$=$	$= \beta_{5,17\frac{1}{2}}$	$= \beta_{5,35}$
$\beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} = \beta_{R_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}, T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}}$			$\bigotimes_{i=0}^{1} \beta_{s_i}^{\mathrm{l.o.}f_n} = \beta_{5,30}$	$\bigotimes_{i=0}^{1} \beta_{s_i}^{\mathrm{l.o.}f_n} = \beta_{5,60}$
D^{f_n}			$\begin{aligned} \beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} &= b^{f_n} \\ 5 \cdot [t-30]^+ &= 25 \\ t &= 35 \end{aligned}$	$\begin{aligned} \beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} &= b^{f_n} \\ 5 \cdot [t-60]^+ &= 25 \\ t &= 65 \end{aligned}$
B^{f_n}			$\begin{aligned} \alpha^{f_n}(T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}) &= 5 \cdot 30 + 25 \\ &= 175 \end{aligned}$	$\begin{aligned} \alpha^{f_n}(T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}) &= 5 \cdot 60 + 25 \\ &= 325 \end{aligned}$

<table>
<tr><td colspan="2">PMOO</td><td>ARB_MUX</td></tr>
<tr><td rowspan="2">s_0</td><td>$\alpha_{s_0}^{\bar{x}f_n}$</td><td>$= \gamma_{5,25}$</td></tr>
<tr><td>$\alpha_{s_0}^{xf_n}$</td><td>$= \gamma_{5,25}$</td></tr>
<tr><td rowspan="2">s_1</td><td>$\alpha_{s_1}^{\bar{x}f_n}$</td><td>$= \gamma_{0,0}$</td></tr>
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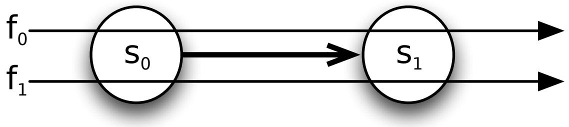
<tr><td rowspan="3">$\beta_{\text{e2e}}^{\text{l.o.}f_n} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_n}, T_{\text{e2e}}^{\text{l.o.}f_n}}$</td><td>$R_{\text{e2e}}^{\text{l.o.}f_n} = \bigwedge_{i \in \{0,1\}} \left(R_{s_i} - r_{s_i}^{xf_n}\right)$</td><td>$\begin{aligned} &= (10-5) \wedge (10-5) \\ &= 5 \end{aligned}$</td></tr>
<tr><td>$T_{\text{e2e}}^{\text{l.o.}f_n} = \sum_{i \in \{0,1\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}f_n} + r_{s_i}^{xf_n} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_n}}\right)$</td><td>$\begin{aligned} &= 10 + \frac{25 + 5 \cdot 10}{5} + 10 + \frac{0 + 5 \cdot 10}{5} \\ &= 45 \end{aligned}$</td></tr>
<tr><td>$=$</td><td>$= \beta_{5,45}$</td></tr>
<tr><td colspan="2">D^{f_n}</td><td>$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_n} &= b^{f_n} \\ 5 \cdot [t - 45]^+ &= 25 \\ t &= 50 \end{aligned}$</td></tr>
<tr><td colspan="2">B^{f_n}</td><td>$\begin{aligned} \alpha^{f_n}(T_{\text{e2e}}^{\text{l.o.}f_n}) &= 5 \cdot 45 + 25 \\ &= 250 \end{aligned}$</td></tr>
</table>

Tandem_2SCs_2Flows_1AC_1Path



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

$\mathrm{arrivalBound}(s_1, \{f_0\}, \{f_1\}) = \alpha_{s_1}^{f_0}$ $= \mathrm{arrivalBound}(s_1, \{f_1\}, \{f_0\}) = \alpha_{s_1}^{f_1}$		FIFO_MUX	ARB_MUX
$\alpha_{s_0}^{f_n}$		$= \gamma_{2\frac{1}{2}, 12\frac{1}{2}}$	
$\alpha_{s_0}^{xf_n}$		$= \gamma_{0,0}$	
$\beta_{s_0}^{\mathrm{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\mathrm{l.o.}f_n}, T_{s_0}^{\mathrm{l.o.}f_n}}$		$= \beta_{10,10}$	
$\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\mathrm{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$	$r_{s_1}^{f_n}$	$= 2\frac{1}{2}$	
	$b_{s_1}^{f_n}$	$\alpha^{f_n}(T_{s_0}^{\mathrm{l.o.}f_n}) = 2\frac{1}{2} \cdot 10 + 12\frac{1}{2} = 37\frac{1}{2}$	
	$=$	$= \gamma_{2\frac{1}{2}, 37\frac{1}{2}}$	

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

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

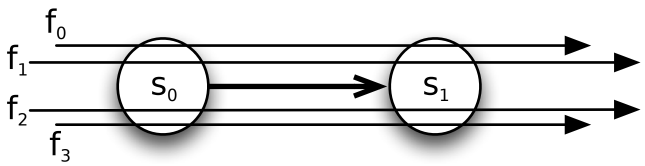
TFA results will be equal for all flows as they share the same path of servers.

	TFA	FIFO_MUX	ARB_MUX
s_0	$\alpha_{s_0} = \alpha^{f_0} + \alpha^{f_1}$	$= \gamma_{5,25}$	
	$D_{s_0}^{f_n}$	$\begin{aligned} \beta_{s_0} &= b_{s_0} \\ 10 \cdot [t-10]^+ &= 25 \\ t &= 12\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_0} &= \alpha_{s_0} \\ 10 \cdot [t-10]^+ &= 5 \cdot t + 25 \\ t &= 25 \end{aligned}$
	$B_{s_0}^{f_n}$	$\begin{aligned} \alpha_{s_0}(T_{s_0}) &= 5 \cdot 10 + 25 \\ &= 75 \end{aligned}$	
s_1	$\alpha_{s_1} = \alpha_{s_1}^{\{f_0, f_1\}}$	$= \gamma_{5,75}$	
	$D_{s_1}^{f_n}$	$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 6 \cdot [t-6]^+ &= 75 \\ t &= 18\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1} \\ 6 \cdot [t-6]^+ &= 5 \cdot t + 75 \\ t &= 111 \end{aligned}$
	$B_{s_1}^{f_n}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 5 \cdot 6 + 75 \\ &= 105 \end{aligned}$	
	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	$\alpha_{s_0}^{xf_n}$		$= \gamma_{2\frac{1}{2},12\frac{1}{2}}$	
	$\beta_{s_0}^{\mathrm{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n}$	$R_{s_0}^{\mathrm{l.o.}f_n}$	$= 7\frac{1}{2}$	
		$T_{s_0}^{\mathrm{l.o.}f_n}$	$\begin{aligned} \beta_{s_0} &= b_{s_0}^{xf_n} \\ 10 \cdot [t-10]^+ &= 12\frac{1}{2} \\ t &= 11\frac{1}{4} \end{aligned}$	$\begin{aligned} \beta_{s_0} &= \alpha_{s_0}^{xf_n} \\ 10 \cdot [t-10]^+ &= 2\frac{1}{2} \cdot t + 12\frac{1}{2} \\ t &= 15 \end{aligned}$
		$=$	$= \beta_{7\frac{1}{2},11\frac{1}{4}}$	$= \beta_{7\frac{1}{2},15}$
s_1	$\alpha_{s_1}^{xf_n}$		$= \gamma_{2\frac{1}{2},37\frac{1}{2}}$	
	$\beta_{s_1}^{\mathrm{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n}$	$R_{s_1}^{\mathrm{l.o.}f_n}$	$= 3\frac{1}{2}$	
		$T_{s_1}^{\mathrm{l.o.}f_n}$	$\begin{aligned} \beta_{s_1} &= b_{s_1}^{xf_n} \\ 6 \cdot [t-6]^+ &= 37\frac{1}{2} \\ t &= 12\frac{1}{4} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1}^{xf_n} \\ 6 \cdot [t-6]^+ &= 2\frac{1}{2} \cdot t + 37\frac{1}{2} \\ t &= 21 \end{aligned}$
		$=$	$= \beta_{3\frac{1}{2},12\frac{1}{4}}$	$= \beta_{3\frac{1}{2},21}$
$\beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} = \beta_{R_{\mathrm{e2e}}^{\mathrm{l.o.}f_n},T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}}$			$\bigotimes_{i=0}^{1} \beta_{s_i}^{\mathrm{l.o.}f_n} = \beta_{3\frac{1}{2},23\frac{1}{2}}$	$\bigotimes_{i=0}^{1} \beta_{s_i}^{\mathrm{l.o.}f_n} = \beta_{3\frac{1}{2},36}$
D^{f_n}			$\begin{aligned} \beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} &= b^{f_n} \\ 3\frac{1}{2} \cdot [t-23\frac{1}{2}]^+ &= 12\frac{1}{2} \\ t &= 27\frac{1}{14} \end{aligned}$	$\begin{aligned} \beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} &= b^{j_i} \\ 3\frac{1}{2} \cdot [t-36]^+ &= 12\frac{1}{2} \\ t &= 39\frac{4}{7} \end{aligned}$
B^{f_n}			$\begin{aligned} \alpha^{f_n}(T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}) &= 2\frac{1}{2} \cdot 23\frac{1}{2} + 12\frac{1}{2} \\ &= 71\frac{1}{4} \end{aligned}$	$\begin{aligned} \alpha^{f_n}(T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}) &= 2\frac{1}{2} \cdot 36 + 12\frac{1}{2} \\ &= 102\frac{1}{2} \end{aligned}$

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

Tandem_1SCs_4Flows_1ACs_1Path



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

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

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

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

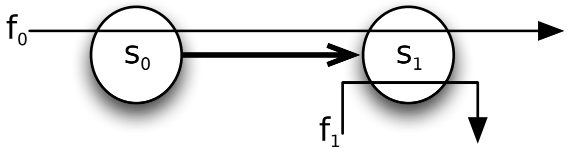
TFA results will be equal for all flows as they share the same path of servers.

TFA		FIFO_MUX	ARB_MUX
s_0	$\alpha_{s_0} = \sum_{n=0}^{3} \alpha^{f_n}$	$= \gamma_{8,40}$	
	$D_{s_0}^{f_n}$	$\beta_{s_0} = b_{s_0}$ $10 \cdot [t-10]^+ = 40$ $t = 14$	$\beta_{s_0} = \alpha_{s_0}$ $10 \cdot [t-10]^+ = 8 \cdot t + 40$ $t = 70$
	$B_{s_0}^{f_n}$	$\alpha_{s_0}(T_{s_0}) = 8 \cdot 10 + 40$ $= 120$	
s_1	$\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_1,f_2,f_3\}}$	$= \gamma_{8,120}$	
	$D_{s_1}^{f_n}$	$\beta_{s_1} = b_{s_1}$ $10 \cdot [t-10]^+ = 120$ $t = 22$	$\beta_{s_1} = \alpha_{s_1}$ $10 \cdot [t-10]^+ = 8 \cdot t + 120$ $t = 110$
	$B_{s_1}^{f_n}$	$\alpha_{s_1}(T_{s_1}) = 8 \cdot 10 + 120$ $= 200$	
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	$\alpha_{s_0}^{xf_n} = \sum_{k=0}^{2} \alpha^{f_k}$		$= \gamma_{6,30}$	
	$\beta_{s_0}^{\mathrm{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n}$	$R_{s_0}^{\mathrm{l.o.}f_n}$	$= 4$	
		$T_{s_0}^{\mathrm{l.o.}f_n}$	$\beta_{s_0} = b_{s_0}^{xf_n}$ $10 \cdot [t-10]^{+} = 30$ $t = 13$	$\beta_{s_0} = \alpha_{s_0}^{xf_n}$ $10 \cdot [t-10]^{+} = 6 \cdot t + 30$ $t = 32\frac{1}{2}$
		$=$	$= \beta_{4,13}$	$= \beta_{4,32\frac{1}{2}}$
s_1	$\alpha_{s_1}^{xf_n} = \alpha_{s_1}^{xf_n}$		$= \gamma_{6,90}$	
	$\beta_{s_1}^{\mathrm{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n}$	$R_{s_1}^{\mathrm{l.o.}f_n}$	$= 4$	
		$T_{s_1}^{\mathrm{l.o.}f_n}$	$\beta_{s_1} = b_{s_1}^{xf_n}$ $10 \cdot [t-10]^{+} = 90$ $t = 19$	$\beta_{s_1} = \alpha_{s_1}^{xf_n}$ $10 \cdot [t-10]^{+} = 4 \cdot t + 90$ $t = 47\frac{1}{2}$
		$=$	$= \beta_{4,19}$	$= \beta_{4,47\frac{1}{2}}$
$\beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}$			$\bigotimes_{i=0}^{1} \beta_{s_i}^{\mathrm{l.o.}f_n} = \beta_{4,32}$	$\bigotimes_{i=0}^{1} \beta_{s_i}^{\mathrm{l.o.}f_n} = \beta_{4,80}$
D^{f_n}			$\beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} = b^{f_n}$ $4 \cdot [t-32]^{+} = 10$ $t = 34\frac{1}{2}$	$\beta_{\mathrm{e2e}}^{\mathrm{l.o.}f_n} = b^{f_n}$ $4 \cdot [t-80]^{+} = 10$ $t = 82\frac{1}{2}$
B^{f_n}			$\alpha^{f_n}(T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}) = 2 \cdot 32 + 10$ $= 74$	$\alpha^{f_n}(T_{\mathrm{e2e}}^{\mathrm{l.o.}f_n}) = 2 \cdot 80 + 10$ $= 170$

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

Tandem_1SC_2Flows_1AC_2Paths



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

<table>
<tr><th colspan="2">arrivalBound$(s_1, \{f_0\}, \mathcal{G})$ $\mathcal{G} \in \mathcal{P}(\mathcal{F}) = \alpha_{s_1}^{f_0}$</th><th>FIFO_MUX</th><th>ARB_MUX</th></tr>
<tr><td colspan="2">$\alpha_{s_0}^{f_0}$</td><td colspan="2">$= \gamma_{5,25}$</td></tr>
<tr><td colspan="2">$\alpha_{s_0}^{x(f_0)}$</td><td colspan="2">$= \gamma_{0,0}$</td></tr>
<tr><td colspan="2">$\beta_{s_0}^{\text{l.o.} f_0} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_0)} = \beta_{R_{s_0}^{\text{l.o.} f_0}, T_{s_0}^{\text{l.o.} f_0}}$</td><td colspan="2">$= \beta_{10,10}$</td></tr>
<tr><td rowspan="3">$\alpha_{s_1}^{f_0} = \alpha_{s_0}^{f_0} \oslash \beta_{s_0}^{\text{l.o.} f_0} = \gamma_{r_{s_1}^{f_0}, b_{s_1}^{f_0}}$</td><td>$r_{s_1}^{f_0}$</td><td colspan="2">$= 5$</td></tr>
<tr><td>$b_{s_1}^{f_0}$</td><td colspan="2">$\alpha^{f_0}(T_{s_0}^{\text{l.o.} f_0}) = 5 \cdot 10 + 25 = 125$</td></tr>
<tr><td>$=$</td><td colspan="2">$= \gamma_{5,125}$</td></tr>
</table>

Flow f_0

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

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

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

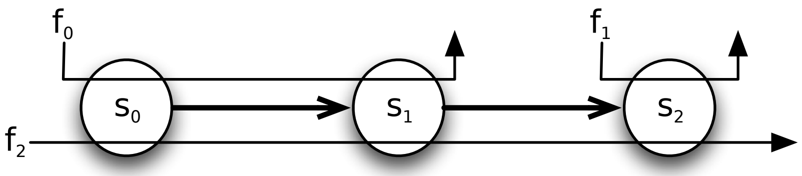
Flow f_1

TFA		FIFO_MUX	ARB_MUX
s_1	$\alpha_{s_1} = \alpha_{s_1}^{f_1} + \alpha_{s_1}^{f_0}$	$= \gamma_{5,25} + \gamma_{5,125} = \gamma_{10,150}$	
	$D_{s_1}^{f_1}$	$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 20 \cdot [t-20]^+ &= 150 \\ t &= 27\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 150 \\ t &= 55 \end{aligned}$
	$B_{s_1}^{f_1}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 10 \cdot 20 + 150 \\ &= 350 \end{aligned}$	
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	$\alpha_{s_1}^{x(f_1)} = \alpha_{s_1}^{f_0}$		$= \gamma_{5,125}$	
	$\beta_{s_1}^{\text{l.o.}f_1} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_1)} = \beta_{R_{s_1}^{\text{l.o.}f_1}, T_{s_1}^{\text{l.o.}f_1}}$	$R_{s_1}^{\text{l.o.}f_1}$	$= 15$	
		$T_{s_1}^{\text{l.o.}f_1}$	$\begin{aligned} \beta_{s_1} &= b_{s_1}^{x(f_1)} \\ 20 \cdot [t-20]^+ &= 125 \\ t &= 26\frac{1}{4} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1}^{x(f_1)} \\ 20 \cdot [t-20]^+ &= 5 \cdot t + 125 \\ t &= 35 \end{aligned}$
		$=$	$= \beta_{15,26\frac{1}{4}}$	$= \beta_{15,35}$
$\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_1}, T_{\text{e2e}}^{\text{l.o.}f_1}}$			$\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,26\frac{1}{4}}$	$\bigotimes_{i=0}^{1} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,35}$
D^{f_1}			$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_1} &= b^{f_1} \\ 15 \cdot [t - 26\frac{1}{4}]^+ &= 25 \\ t &= 27\frac{11}{12} \end{aligned}$	$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_1} &= b^{f_1} \\ 15 \cdot [t-35]^+ &= 25 \\ t &= 36\frac{2}{3} \end{aligned}$
B^{f_1}			$\begin{aligned} \alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) &= 5 \cdot 26\frac{1}{4} + 25 \\ &= 156\frac{1}{4} \end{aligned}$	$\begin{aligned} \alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) &= 5 \cdot 35 + 25 \\ &= 200 \end{aligned}$

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

Tandem_1SC_3Flows_1AC_3Paths



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

$\mathrm{arrivalBound}(s_1, \{f_0\}, \{f_2\}) = \alpha_{s_1}^{f_0}$ $= \mathrm{arrivalBound}(s_1, \{f_2\}, \{f_0\}) = \alpha_{s_1}^{f_2}$		FIFO_MUX	ARB_MUX
$\alpha_{s_0}^{f_n}, n \in \{0, 2\}$		$= \gamma_{5,25}$	
$\alpha_{s_0}^{xf_n}$		$= \gamma_{0,0}$	
$\beta_{s_0}^{\mathrm{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{xf_n} = \beta_{R_{s_0}^{\mathrm{l.o.}f_n}, T_{s_0}^{\mathrm{l.o.}f_n}}$		$= \beta_{20,20}$	
$\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\mathrm{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$	$r_{s_1}^{f_n}$	$= 5$	
	$b_{s_1}^{f_n}$	$\alpha_{s_0}^{f_n}(T_{s_0}^{\mathrm{l.o.}f_n}) = 5 \cdot 20 + 25 = 125$	
	$=$	$= \gamma_{5,125}$	

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

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

PBOO-AB:

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

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

Flow f_0 (comparable to Tandem_1SC_2Flows_1AC_1Path)

<table>
<tr><td colspan="2">TFA</td><td>FIFO_MUX</td><td>ARB_MUX</td></tr>
<tr><td rowspan="3">s_0</td><td>$\alpha_{s_0} = \alpha^{f_0} + \alpha^{f_1}$</td><td colspan="2">$= \gamma_{10,50}$</td></tr>
<tr><td>$D^{f_0}_{s_0}$</td><td>$\begin{aligned} \beta_{s_0} =& \quad b_{s_0} \\ 20 \cdot [t-20]^+ =& \quad 50 \\ t =& \quad 22\frac{1}{2} \end{aligned}$</td><td>$\begin{aligned} \beta_{s_0} =& \quad \alpha_{s_0} \\ 20 \cdot [t-20]^+ =& \quad 10 \cdot t + 50 \\ t =& \quad 45 \end{aligned}$</td></tr>
<tr><td>$B^{f_0}_{s_0}$</td><td colspan="2">$\begin{aligned} \alpha_{s_0}(T_{s_0}) =& \quad 20 \cdot 10 + 50 \\ =& \quad 250 \end{aligned}$</td></tr>
<tr><td rowspan="3">s_1</td><td>$\alpha_{s_1} = \alpha^{\{f_0,f_2\}}_{s_1}$</td><td colspan="2">$= \gamma_{10,250}$</td></tr>
<tr><td>$D^{f_0}_{s_1}$</td><td>$\begin{aligned} \beta_{s_1} =& \quad b_{s_1} \\ 20 \cdot [t-20]^+ =& \quad 250 \\ t =& \quad 32\frac{1}{2} \end{aligned}$</td><td>$\begin{aligned} \beta_{s_1} =& \quad \alpha_{s_1} \\ 20 \cdot [t-20]^+ =& \quad 10 \cdot t + 250 \\ t =& \quad 65 \end{aligned}$</td></tr>
<tr><td>$B^{f_0}_{s_1}$</td><td colspan="2">$\begin{aligned} \alpha_{s_1}(T_{s_1}) =& \quad 10 \cdot 20 + 250 \\ =& \quad 450 \end{aligned}$</td></tr>
<tr><td colspan="2">D^{f_0}</td><td>$\sum_{i=0}^{1} D^{f_0}_{s_i} = 55$</td><td>$\sum_{i=0}^{1} D^{f_0}_{s_i} = 110$</td></tr>
<tr><td colspan="2">B^{f_0}</td><td colspan="2">$\max_{i=\{0,1\}} b^{f_0}_{s_i} = 450$</td></tr>
</table>

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

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

Flow f_1 (comparable with Node_2Flows_2ACs)

PBOO-AB:

TFA		FIFO_MUX	ARB_MUX
s_2	$\alpha_{s_2} = \alpha^{f_1} + \alpha^{f_2}_{s_1 s_2}$	$\gamma_{5,25} + \gamma_{5,264\frac{1}{16}} = \gamma_{10,289\frac{1}{16}}$	$\gamma_{5,25} + \gamma_{5,355\frac{5}{9}} = \gamma_{10,380\frac{5}{9}}$
	$D^{f_1}_{s_2}$	$\beta_{s_2} = b_{s_2}$ $20 \cdot [t-20]^+ = 289\frac{1}{16}$ $t = 34\frac{29}{64}$	$\beta_{s_2} = \alpha_{s_2}$ $20 \cdot [t-20]^+ = 10 \cdot t + 380\frac{5}{9}$ $t = 78\frac{5}{90}$
	$B^{f_1}_{s_2}$	$\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 289\frac{1}{16}$ $= 489\frac{1}{16}$	$\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 380\frac{5}{9}$ $= 580\frac{5}{9}$
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	$\alpha_{s_2} = \alpha^{f_1} + \alpha^{f_2}_{s_1 s_2}$	$\gamma_{5,25} + \gamma_{5,300} = \gamma_{10,325}$
	$D^{f_1}_{s_2}$	$\beta_{s_2} = \alpha_{s_2}$ $20 \cdot [t-20]^+ = 10 \cdot t + 325$ $t = 72\frac{1}{2}$
	$B^{f_1}_{s_2}$	$\alpha_{s_2}(T_{s_2}) = 10 \cdot 20 + 325$ $= 525$
D^{f_1}		$= 72\frac{1}{2}$
B^{f_1}		$= 525$

PBOO-AB:

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

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

PMOO-AB:

<table>
<tr><th colspan="3">SFA</th><th>ARB_MUX</th></tr>
<tr><td rowspan="4">s_2</td><td colspan="2">$\alpha_{s_2}^{x(f_1)} = \alpha_{s_2}^{f_2}$</td><td>$= \gamma_{5,300}$</td></tr>
<tr><td rowspan="3">$\beta_{s_2}^{\text{l.o.}f_1} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_1)} = \beta_{s_2} \ominus \alpha_{s_1 s_2}^{x(f_1)}$</td><td>$R_{s_2}^{\text{l.o.}f_1}$</td><td>$= 15$</td></tr>
<tr><td>$T_{s_2}^{\text{l.o.}f_1}$</td><td>$$\begin{aligned} \beta_{s_2} &= \alpha_{s_2}^{x(f_1)} \\ 20 \cdot [t-20]^+ &= 5 \cdot t + 300 \\ t &= 46\frac{2}{3} \end{aligned}$$</td></tr>
<tr><td>$=$</td><td>$=\beta_{15,46\frac{2}{3}}$</td></tr>
<tr><td colspan="3">$\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{s_2}^{\text{l.o.}f_1}$</td><td>$=\beta_{15,46\frac{2}{3}}$</td></tr>
<tr><td colspan="3">D^{f_1}</td><td>$$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_1} &= b^{f_1} \\ 15 \cdot [t - 46\frac{2}{3}]^+ &= 25 \\ t &= 48\frac{1}{3} \end{aligned}$$</td></tr>
<tr><td colspan="3">B^{f_1}</td><td>$$\begin{aligned} \alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) &= 5 \cdot 46\frac{2}{3} + 25 \\ &= 258\frac{1}{3} \end{aligned}$$</td></tr>
</table>

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

Flow f_2

PBOO-AB:

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

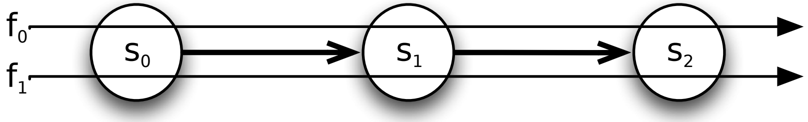
PMOO-AB:

	TFA	ARB_MUX
s_0	$\alpha_{s_0} = \alpha_{s_0}^{f_0} + \alpha_{s_0}^{f_1}$	$= \gamma_{10,50}$
	$D_{s_0}^{f_2}$	$\begin{aligned} \beta_{s_0} &= \alpha_{s_0} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 50 \\ t &= 45 \end{aligned}$
	$B_{s_0}^{f_2}$	$\begin{aligned} \alpha_{s_0}(T_{s_0}) &= 20 \cdot 10 + 50 \\ &= 250 \end{aligned}$
s_1	$\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_1\}}$	$= \gamma_{10,250}$
	$D_{s_1}^{f_2}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 250 \\ t &= 65 \end{aligned}$
	$B_{s_1}^{f_2}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 10 \cdot 20 + 250 \\ &= 450 \end{aligned}$
s_2	$\alpha_{s_2} = \alpha^{f_1} + \alpha_{s_1 s_2}^{f_2}$	$\gamma_{5,25} + \gamma_{5,300} = \gamma_{10,325}$
	$D_{s_2}^{f_1}$	$\begin{aligned} \beta_{s_2} &= \alpha_{s_2} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 325 \\ t &= 72\frac{1}{2} \end{aligned}$
	$B_{s_2}^{f_1}$	$\begin{aligned} \alpha_{s_2}(T_{s_2}) &= 10 \cdot 20 + 325 \\ &= 525 \end{aligned}$
	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	$\alpha_{s_0}^{x(f_2)} = \alpha_{s_0}^{f_0}$		$= \gamma_{5,25}$	
	$\beta_{s_0}^{\text{l.o.}f_2} = \beta_{s_0} \ominus \alpha_{s_0}^{x(f_2)} = \beta_{s_0} \ominus \alpha_{s_0}^{f_0}$	$R_{s_0}^{\text{l.o.}f_2}$	$= 5$	
		$T_{s_0}^{\text{l.o.}f_2}$	$\beta_{s_0} = b_{s_0}^{x(f_2)}$ $20 \cdot [t-20]^+ = 25$ $t = 21\frac{1}{4}$	$\beta_{s_0} = \alpha_{s_0}^{x(f_2)}$ $20 \cdot [t-20]^+ = 5 \cdot t + 25$ $t = 28\frac{1}{3}$
		$=$	$= \beta_{15,21\frac{1}{4}}$	$= \beta_{15,28\frac{1}{3}}$
s_1	$\alpha_{s_1}^{x(f_2)} = \alpha_{s_1}^{x(f_2)}$		$= \gamma_{5,125}$	
	$\beta_{s_1}^{\text{l.o.}f_2} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_2)}$	$R_{s_1}^{\text{l.o.}f_2}$	$= 15$	
		$T_{s_1}^{\text{l.o.}f_2}$	$\beta_{s_1} = b_{s_1}^{x(f_2)}$ $20 \cdot [t-20]^+ = 125$ $t = 26\frac{1}{4}$	$\beta_{s_1} = \alpha_{s_1}^{x(f_2)}$ $20 \cdot [t-20]^+ = 5 \cdot t + 125$ $t = 35$
		$=$	$= \beta_{15,26\frac{1}{4}}$	$= \beta_{15,35}$
s_2	$\alpha_{s_2}^{x(f_2)} = \alpha_{s_2}^{f_1}$		$= \gamma_{5,25}$	
	$\beta_{s_2}^{\text{l.o.}f_2} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_2)} = \beta_{s_2} \ominus \alpha^{f_1}$	$R_{s_2}^{\text{l.o.}f_2}$	$= 15$	
		$T_{s_2}^{\text{l.o.}f_2}$	$\beta_{s_2} = b_{s_2}^{x(f_2)}$ $20 \cdot [t-20]^+ = 25$ $t = 21\frac{1}{4}$	$\beta_{s_2} = \alpha_{s_2}^{x(f_2)}$ $20 \cdot [t-20]^+ = 5 \cdot t + 25$ $t = 28\frac{1}{3}$
		$=$	$= \beta_{15,21\frac{1}{4}}$	$= \beta_{15,28\frac{1}{3}}$
	$\beta_{\text{e2e}}^{\text{l.o.}f_2}$		$\bigotimes_{i=0}^{2} \beta_{s_i}^{\text{l.o.}f_2} = \beta_{15,68\frac{3}{4}}$	$\bigotimes_{i=0}^{2} \beta_{s_i}^{\text{l.o.}f_0} = \beta_{15,91\frac{2}{3}}$
	D^{f_2}		$\beta_{\text{e2e}}^{\text{l.o.}f_2} = b^{f_2}$ $15 \cdot [t - 68\frac{3}{4}]^+ = 25$ $t = 70\frac{5}{12}$	$\beta_{\text{e2e}}^{\text{l.o.}f_2} = b^{f_2}$ $15 \cdot [t - 91\frac{2}{3}]^+ = 25$ $t = 93\frac{1}{3}$
	B^{f_2}		$\alpha^{f_2}(T_{s_2}^{\text{l.o.}f_2}) = 5 \cdot 68\frac{3}{4} + 25$ $= 368\frac{3}{4}$	$\alpha^{f_2}(T_{\text{e2e}}^{\text{l.o.}f_2}) = 5 \cdot 91\frac{2}{3} + 25$ $= 483\frac{1}{3}$

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

Tandem_1SC_2Flows_1AC_1Path_v2



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

<table>
<tr><th colspan="2">arrivalBound$(s_1, \{f_0, f_1\}, \{\}) = \alpha_{s_1}^{\{f_0,f_1\}}$</th><th>FIFO_MUX</th><th>ARB_MUX</th></tr>
<tr><td colspan="2">$\alpha_{s_0}^{\{f_0,f_1\}}$</td><td colspan="2">$= \gamma_{10,50}$</td></tr>
<tr><td colspan="2">$\alpha_{s_0}^{x\{f_0,f_1\}}$</td><td colspan="2">$= \gamma_{0,0}$</td></tr>
<tr><td colspan="2">$\beta_{s_0}^{\text{l.o.}\{f_0,f_1\}} = \beta_{s_0} \ominus \alpha_{s_0}^{x\{f_0,f_1\}} = \beta_{R_{s_0}^{\text{l.o.}\{f_0,f_1\}}, T_{s_0}^{\text{l.o.}\{f_0,f_1\}}}$</td><td colspan="2">$= \beta_{20,20}$</td></tr>
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<tr><td>$b_{s_1}^{\{f_0,f_1\}}$</td><td colspan="2">$\alpha_{s_0}^{\{f_0,f_1\}}(T_{s_0}^{\text{l.o.}\{f_0,f_1\}}) = 10 \cdot 20 + 50 = 250$</td></tr>
<tr><td>$=$</td><td colspan="2">$= \gamma_{10,250}$</td></tr>
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<tr><td colspan="2">$\alpha_{s_1}^{x\{f_0,f_1\}}$</td><td colspan="2">$= \gamma_{0,0}$</td></tr>
<tr><td colspan="2">$\beta_{s_1}^{\text{l.o.}\{f_0,f_1\}} = \beta_{s_1} \ominus \alpha_{s_1}^{x\{f_0,f_1\}} = \beta_{R_{s_1}^{\text{l.o.}\{f_0,f_1\}}, T_{s_1}^{\text{l.o.}\{f_0,f_1\}}}$</td><td colspan="2">$= \beta_{20,20}$</td></tr>
<tr><td rowspan="3">$\alpha_{s_2}^{\{f_0,f_1\}} = \alpha_{s_1}^{\{f_0,f_1\}} \oslash \beta_{s_1}^{\text{l.o.}\{f_0,f_1\}} = \gamma_{r_{s_2}^{\{f_0,f_1\}}, b_{s_2}^{\{f_0,f_1\}}}$</td><td>$r_{s_2}^{\{f_0,f_1\}}$</td><td colspan="2">$= 10$</td></tr>
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<tr><td>$=$</td><td colspan="2">$= \gamma_{10,450}$</td></tr>
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<tr><td colspan="2">$\alpha_{s_0}^{f_n}$</td><td colspan="2">$= \gamma_{5,25}$</td></tr>
<tr><td colspan="2">$\alpha_{s_0}^{x f_n}$</td><td colspan="2">$= \gamma_{0,0}$</td></tr>
<tr><td colspan="2">$\beta_{s_0}^{\text{l.o.}f_n} = \beta_{s_0} \ominus \alpha_{s_0}^{x f_n} = \beta_{R_{s_0}^{\text{l.o.}f_n}, T_{s_0}^{\text{l.o.}f_n}}$</td><td colspan="2">$= \beta_{20,20}$</td></tr>
<tr><td rowspan="3">$\alpha_{s_1}^{f_n} = \alpha_{s_0}^{f_n} \oslash \beta_{s_0}^{\text{l.o.}f_n} = \gamma_{r_{s_1}^{f_n}, b_{s_1}^{f_n}}$</td><td>$r_{s_1}^{f_n}$</td><td colspan="2">$= 5$</td></tr>
<tr><td>$b_{s_1}^{f_n}$</td><td colspan="2">$\alpha^{f_n}(T_{s_0}^{\text{l.o.}f_n}) = 5 \cdot 20 + 25 = 125$</td></tr>
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<tr><td colspan="2">$\alpha_{s_1}^{f_n}$</td><td colspan="2">$= \gamma_{5,125}$</td></tr>
<tr><td colspan="2">$\alpha_{s_1}^{xf_n}$</td><td colspan="2">$= \gamma_{0,0}$</td></tr>
<tr><td colspan="2">$\beta_{s_1}^{\mathrm{l.o.}f_n} = \beta_{s_1} \ominus \alpha_{s_1}^{xf_n} = \beta_{R_{s_1}^{\mathrm{l.o.}f_n}, T_{s_1}^{\mathrm{l.o.}f_n}}$</td><td colspan="2">$= \beta_{20,20}$</td></tr>
<tr><td rowspan="3">$\alpha_{s_2}^{f_n} = \alpha_{s_1}^{f_n} \oslash \beta_{s_1}^{\mathrm{l.o.}f_n} = \gamma_{r_{s_2}^{f_n}, b_{s_2}^{f_n}}$</td><td>$r_{s_2}^{f_n}$</td><td colspan="2">$= 5$</td></tr>
<tr><td>$b_{s_2}^{f_n}$</td><td colspan="2">$\alpha_{s_1}^{f_n}(T_{s_1}^{\mathrm{l.o.}f_n}) = 5 \cdot 20 + 125 = 225$</td></tr>
<tr><td>$=$</td><td colspan="2">$= \gamma_{5,125}$</td></tr>
</table>

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

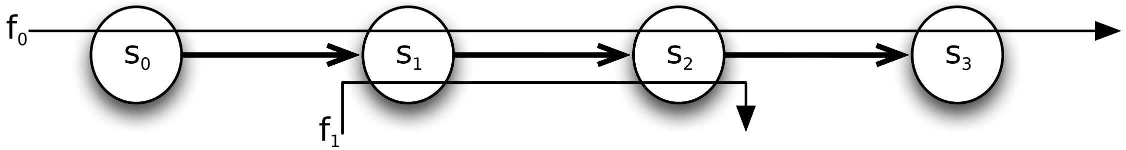
TFA results will be equal for all flows as they share the same path of servers.

	TFA	FIFO_MUX	ARB_MUX
s_0	$\alpha_{s_0} = \alpha_{s_0}^{f_0} + \alpha_{s_0}^{f_1}$	$= \gamma_{10,50}$	
	$D_{s_0}^{f_n}$	$\begin{aligned} \beta_{s_0} &= b_{s_0} \\ 20 \cdot [t-20]^+ &= 50 \\ t &= 22\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_0} &= \alpha_{s_0} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 50 \\ t &= 45 \end{aligned}$
	$B_{s_0}^{f_n}$	$\begin{aligned} \alpha_{s_0}(T_{s_0}) &= 10 \cdot 20 + 50 \\ &= 250 \end{aligned}$	
s_1	$\alpha_{s_1} = \alpha_{s_1}^{\{f_0,f_1\}}$	$= \gamma_{10,250}$	
	$D_{s_1}^{f_n}$	$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 20 \cdot [t-20]^+ &= 250 \\ t &= 32\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 250 \\ t &= 65 \end{aligned}$
	$B_{s_1}^{f_n}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 10 \cdot 20 + 250 \\ &= 450 \end{aligned}$	
s_2	$\alpha_{s_2}^{f_0} = \alpha_{s_2}^{\{f_0,f_1\}}$	$= \gamma_{10,450}$	
	$D_{s_2}^{f_n}$	$\begin{aligned} \beta_{s_2} &= b_{s_2} \\ 20 \cdot [t-20]^+ &= 450 \\ t &= 42\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_2} &= \alpha_{s_2} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 450 \\ t &= 85 \end{aligned}$
	$B_{s_2}^{f_n}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 10 \cdot 20 + 450 \\ &= 650 \end{aligned}$	
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	$\alpha^{xf_n}_{s_0}$		$= \gamma_{5,25}$	
	$\beta^{\text{l.o.}f_n}_{s_0} = \beta_{s_0} \ominus \alpha^{xf_n}_{s_0} = \beta_{R^{\text{l.o.}f_n}_{s_0}, T^{\text{l.o.}f_n}_{s_0}}$	$R^{\text{l.o.}f_n}_{s_0}$	$= 15$	
		$T^{\text{l.o.}f_n}_{s_0}$	$\beta_{s_0} = b^{xf_n}_{s_0}$ $20 \cdot [t-20]^+ = 25$ $t = 22\frac{1}{4}$	$\beta_{s_0} = \alpha^{xf_n}_{s_0}$ $20 \cdot [t-20]^+ = 5 \cdot t + 25$ $t = 28\frac{1}{3}$
		$=$	$= \beta_{15,21\frac{1}{4}}$	$= \beta_{15,28\frac{1}{3}}$
s_1	$\alpha^{xf_n}_{s_1}$		$= \gamma_{5,125}$	
	$\beta^{\text{l.o.}f_n}_{s_1} = \beta_{s_1} \ominus \alpha^{xf_n}_{s_1}$	$R^{\text{l.o.}f_n}_{s_1}$	$= 15$	
		$T^{\text{l.o.}f_n}_{s_1}$	$\beta_{s_1} = b^{xf_n}_{s_1}$ $20 \cdot [t-20]^+ = 125$ $t = 26\frac{1}{4}$	$\beta_{s_1} = \alpha^{xf_n}_{s_1}$ $20 \cdot [t-20]^+ = 5 \cdot t + 125$ $t = 35$
		$=$	$= \beta_{15,26\frac{1}{4}}$	$= \beta_{15,35}$
s_2	$\alpha^{xf_n}_{s_2}$		$= \gamma_{5,225}$	
	$\beta^{\text{l.o.}f_n}_{s_2} = \beta_{s_2} \ominus \alpha^{xf_n}_{s_2}$	$R^{\text{l.o.}f_n}_{s_2}$	$= 15$	
		$T^{\text{l.o.}f_n}_{s_2}$	$\beta_{s_2} = b^{xf_n}_{s_2}$ $20 \cdot [t-20]^+ = 225$ $t = 31\frac{1}{4}$	$\beta_{s_2} = \alpha^{xf_n}_{s_2}$ $20 \cdot [t-20]^+ = 5 \cdot t + 225$ $t = 41\frac{2}{3}$
		$=$	$= \beta_{15,31\frac{1}{4}}$	$= \beta_{15,41\frac{2}{3}}$
$\beta^{\text{l.o.}f_n}_{\text{e2e}} = \beta_{R^{\text{l.o.}f_n}_{\text{e2e}}, T^{\text{l.o.}f_n}_{\text{e2e}}}$			$\bigotimes_{i=0}^{2} \beta^{\text{l.o.}f_n}_{s_i} = \beta_{5,78\frac{3}{4}}$	$\bigotimes_{i=0}^{2} \beta^{\text{l.o.}f_n}_{s_i} = \beta_{5,105}$
D^{f_n}			$\beta^{\text{l.o.}f_n}_{\text{e2e}} = b^{f_n}$ $15 \cdot [t - 78\frac{3}{4}]^+ = 25$ $t = 80\frac{5}{12}$	$\beta^{\text{l.o.}f_n}_{\text{e2e}} = b^{f_n}$ $15 \cdot [t - 105]^+ = 25$ $t = 106\frac{2}{3}$
B^{f_n}			$\alpha^{f_n}(T^{\text{l.o.}f_n}_{\text{e2e}}) = 5 \cdot 78\frac{3}{4} + 25$ $= 418\frac{3}{4}$	$\alpha^{f_n}(T^{\text{l.o.}f_n}_{\text{e2e}}) = 5 \cdot 105 + 25$ $= 550$

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

Tandem_1SC_2Flows_1AC_2Paths_v2



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

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

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

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

$\text{arrivalBound}(s_2, \{f_1\}, \{f_0\}) = \alpha_{s_2}^{f_1}$		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:

arrivalBound$(s_3, \{f_0\}, \{\}) = \alpha_{s_3}^{f_0}$		FIFO_MUX	ARB_MUX
$\alpha_{s_2}^{f_0}$		$= \gamma_{5,231\frac{1}{4}}$	$= \gamma_{5,266\frac{2}{3}}$
$\alpha_{s_2}^{x(f_0)}$		$= \gamma_{5,125}$	
$\beta_{s_2}^{\text{l.o.}f_0} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_0)}$	$R_{s_2}^{\text{l.o.}f_0}$	$= 15$	
	$T_{s_2}^{\text{l.o.}f_0}$	$\begin{aligned} \beta_{s_2} &= b_{s_2}^{x(f_0)} \\ 20 \cdot [t-20]^+ &= 156\frac{1}{4} \\ t &= 27\frac{13}{16} \end{aligned}$	$\begin{aligned} \beta_{s_2} &= \alpha_{s_2}^{x(f_0)} \\ 20 \cdot [t-20]^+ &= 5 \cdot t + 200 \\ t &= 40 \end{aligned}$
	$=$	$=\beta_{15,27\frac{13}{16}}$	$=\beta_{15,40}$
$\alpha_{s_3}^{f_0} = \alpha_{s_2}^{f_0} \oslash \beta_{s_2}^{\text{l.o.}f_0} = \gamma_{r_{s_3}^{f_1}, b_{s_3}^{f_1}}$	$r_{s_3}^{f_0}$	$= 5$	
	$b_{s_3}^{f_0}$	$\alpha_{s_2}^{f_0}(T_{s_2}^{\text{l.o.}f_0}) = 370\frac{5}{16}$	$\alpha_{s_2}^{f_0}(T_{s_2}^{\text{l.o.}f_0}) = 466\frac{2}{3}$
	$=$	$= \gamma_{5,370\frac{5}{16}}$	$= \gamma_{5,466\frac{2}{3}}$

PMOO-AB, ARB_MUX:

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

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.

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

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

$\text{arrivalBound}(s_2, \{f_0, f_1\}, \{\}) = \alpha_{s_2}^{\{f_0,f_1\}}$		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	α_{s_0}	$= \gamma_{5,25}$	
	$D_{s_0}^{f_0}$	$\begin{aligned} \beta_{s_0} &= b_{s_0} \\ 20 \cdot [t-20]^+ &= 25 \\ t &= 21\frac{1}{4} \end{aligned}$	FIFO per microflow $\begin{aligned} \beta_{s_0} &= b_{s_0} \\ 20 \cdot [t-20]^+ &= 25 \\ t &= 21\frac{1}{4} \end{aligned}$
	$B_{s_0}^{f_0}$	$\begin{aligned} \alpha_{s_0}(T_{s_0}) &= 5 \cdot 20 + 25 \\ &= 125 \end{aligned}$	
s_1	$\alpha_{s_1} = \alpha_{s_1}^{f_0} + \alpha_{s_1}^{f_1}$	$= \gamma_{5,125} + \gamma_{5,25} = \gamma_{10,150}$	
	$D_{s_1}^{f_0}$	$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 20 \cdot [t-20]^+ &= 150 \\ t &= 27\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 150 \\ t &= 55 \end{aligned}$
	$B_{s_1}^{f_0}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 10 \cdot 20 + 150 \\ &= 350 \end{aligned}$	
s_2	$\alpha_{s_2} = \alpha_{s_2}^{\{f_0,f_1\}}$	$= \gamma_{10,350}$	
	$D_{s_2}^{f_0}$	$\begin{aligned} \beta_{s_2} &= b_{s_2} \\ 20 \cdot [t-20]^+ &= 350 \\ t &= 37\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_2} &= \alpha_{s_2} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 350 \\ t &= 75 \end{aligned}$
	$B_{s_2}^{f_0}$	$\begin{aligned} \alpha_{s_2}(T_{s_2}) &= 10 \cdot 20 + 350 \\ &= 550 \end{aligned}$	
s_3	$\alpha_{s_3} = \alpha_{s_3}^{f_0}$	$= \gamma_{5,370\frac{5}{16}}$	$= \gamma_{5,466\frac{2}{3}}$
	$D_{s_3}^{f_0}$	$\begin{aligned} \beta_{s_3} &= b_{s_3} \\ 20 \cdot [t-20]^+ &= 370\frac{5}{16} \\ t &= 38\frac{33}{64} \end{aligned}$	FIFO per micro flow $\begin{aligned} \beta_{s_3} &= b_{s_3} \\ 20 \cdot [t-20]^+ &= 466\frac{2}{3} \\ t &= 43\frac{1}{3} \end{aligned}$
	$B_{s_3}^{f_0}$	$\begin{aligned} \alpha_{s_3}(T_{s_3}) &= 5 \cdot 20 + 370\frac{5}{16} \\ &= 470\frac{5}{16} \end{aligned}$	$\begin{aligned} \alpha_{s_3}(T_{s_3}) &= 5 \cdot 20 + 466\frac{2}{3} \\ &= 566\frac{2}{3} \end{aligned}$
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	α_{s_0}	$= \gamma_{5,25}$
	$D^{f_0}_{s_0}$	FIFO per microflow $\beta_{s_0} = b_{s_0}$ $20 \cdot [t-20]^+ = 25$ $t = 21\frac{1}{4}$
	$B^{f_0}_{s_0}$	$\alpha_{s_0}(T_{s_0}) = 125$
s_1	$\alpha_{s_1} = \alpha^{f_0}_{s_1} + \alpha^{f_1}_{s_1}$	$= \gamma_{5,125} + \gamma_{5,25} = \gamma_{10,150}$
	$D^{f_0}_{s_1}$	$\beta_{s_1} = \alpha_{s_1}$ $20 \cdot [t-20]^+ = 10 \cdot t + 150$ $t = 55$
	$B^{f_0}_{s_1}$	$\alpha_{s_1}(T_{s_1}) = 10 \cdot 20 + 150$ $= 350$
s_2	$\alpha_{s_2} = \alpha^{\{f_0,f_1\}}_{s_2}$	$= \gamma_{10,350}$
	$D^{f_0}_{s_2}$	$\beta_{s_2} = \alpha_{s_2}$ $20 \cdot [t-20]^+ = 10 \cdot t + 350$ $t = 75$
	$B^{f_0}_{s_2}$	$\alpha_{s_2}(T_{s_2}) = 550$
s_3	$\alpha_{s_3} = \alpha^{f_0}_{s_3}$	$= \gamma_{5,400}$
	$D^{f_0}_{s_3}$	FIFO per micro flow $\beta_{s_3} = b_{s_3}$ $20 \cdot [t-20]^+ = 400$ $t = 40$
	$B^{f_0}_{s_3}$	$\alpha_{s_3}(T_{s_3}) = 5 \cdot 20 + 400$ $= 500$
D^{f_0}		$\sum_{i=0}^{3} D^{f_0}_{s_i} = 191\frac{1}{4}$
B^{f_0}		$\max_{i=0}^{3} b^{f_0}_{s_i} = 550$

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

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	$\alpha_{s_3}^{\bar{x}(f_0)}$	$= \gamma_{0,0}$
	$\alpha_{s_3}^{x(f_0)}$	$= \gamma_{0,0}$
$\beta_{\text{e2e}}^{\text{l.o.}f_0} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_0}, T_{\text{e2e}}^{\text{l.o.}f_0}}$	$R_{\text{e2e}}^{\text{l.o.}f_0} = \bigwedge_{i\in\{0,1,2,3\}} \left(R_{s_i} - r_{s_i}^{x(f_0)}\right)$	$\begin{aligned} &= (20-0)\wedge(20-5)\wedge(20-5)\wedge(20-0) \\ &= 15 \end{aligned}$
	$T_{\text{e2e}}^{\text{l.o.}f_0} = \sum_{i\in\{0,1,2,3\}} \left(T_{s_i} + \frac{b_{s_i}^{\bar{x}(f_0)} + r_{s_i}^{x(f_0)} \cdot T_{s_i}}{R_{\text{e2e}}^{\text{l.o.}f_0}}\right)$	$\begin{aligned} &= 20 + \frac{0+0\cdot 20}{15} + 20 + \frac{25+5\cdot 20}{15} + 20 + \frac{0+5\cdot 20}{15} + 20 + \frac{0+0\cdot 20}{15} \\ &= 95 \end{aligned}$
	$=$	$= \beta_{15,95}$
D^{f_0}		$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_0} &= b^{f_0} \\ 15\cdot[t-95]^+ &= 25 \\ t &= 96\frac{2}{3} \end{aligned}$
B^{f_0}		$\begin{aligned} \alpha^{f_0}(T_{\text{e2e}}^{\text{l.o.}f_0}) &= 5\cdot 95 + 25 \\ &= 500 \end{aligned}$

Flow f_1

TFA		FIFO_MUX	ARB_MUX
s_1	$\alpha_{s_1} = \alpha_{s_1}^{f_0} + \alpha_{s_1}^{f_1}$	$= \gamma_{5,25} + \gamma_{5,125} = \gamma_{10,150}$	
	$D_{s_1}^{f_1}$	$\begin{aligned} \beta_{s_1} &= b_{s_1} \\ 20 \cdot [t-20]^+ &= 150 \\ t &= 27\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 150 \\ t &= 55 \end{aligned}$
	$B_{s_1}^{f_1}$	$\begin{aligned} \alpha_{s_1}(T_{s_1}) &= 10 \cdot 20 + 150 \\ &= 350 \end{aligned}$	
s_2	$\alpha_{s_2} = \alpha_{s_2}^{\{f_0, f_1\}}$	$= \gamma_{10,350}$	
	$D_{s_2}^{f_1}$	$\begin{aligned} \beta_{s_2} &= b_{s_2} \\ 20 \cdot [t-20]^+ &= 350 \\ t &= 37\frac{1}{2} \end{aligned}$	$\begin{aligned} \beta_{s_2} &= \alpha_{s_2} \\ 20 \cdot [t-20]^+ &= 10 \cdot t + 350 \\ t &= 75 \end{aligned}$
	$B_{s_2}^{f_1}$	$\begin{aligned} \alpha_{s_2}(T_{s_2}) &= 10 \cdot 20 + 350 \\ &= 550 \end{aligned}$	
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	$\alpha_{s_1}^{x(f_1)}$		$= \gamma_{5,125}$	
	$\beta_{s_1}^{\text{l.o.}f_1} = \beta_{s_1} \ominus \alpha_{s_1}^{x(f_1)}$	$R_{s_1}^{\text{l.o.}f_1}$	$= 15$	
		$T_{s_1}^{\text{l.o.}f_1}$	$\begin{aligned} \beta_{s_1} &= b_{s_1}^{x(f_1)} \\ 20 \cdot [t-20]^+ &= 125 \\ t &= 26\frac{1}{4} \end{aligned}$	$\begin{aligned} \beta_{s_1} &= \alpha_{s_1}^{x(f_0)} \\ 20 \cdot [t-20]^+ &= 5 \cdot t + 125 \\ t &= 35 \end{aligned}$
		$=$	$= \beta_{15,26\frac{1}{4}}$	$= \beta_{15,35}$
s_2	$\alpha_{s_2}^{x(f_1)}$		$= \gamma_{5,225}$	
	$\beta_{s_2}^{\text{l.o.}f_1} = \beta_{s_2} \ominus \alpha_{s_2}^{x(f_1)}$	$R_{s_2}^{\text{l.o.}f_1}$	$= 15$	
		$T_{s_2}^{\text{l.o.}f_1}$	$\begin{aligned} \beta_{s_2} &= b_{s_2}^{x(f_1)} \\ 20 \cdot [t-20]^+ &= 225 \\ t &= 31\frac{1}{4} \end{aligned}$	$\begin{aligned} \beta_{s_2} &= \alpha_{s_2}^{x(f_1)} \\ 20 \cdot [t-20]^+ &= 5 \cdot t + 225 \\ t &= 41\frac{2}{3} \end{aligned}$
		$=$	$= \beta_{15,31\frac{1}{4}}$	$= \beta_{15,41\frac{2}{3}}$
$\beta_{\text{e2e}}^{\text{l.o.}f_1} = \beta_{R_{\text{e2e}}^{\text{l.o.}f_1}, T_{\text{e2e}}^{\text{l.o.}f_1}}$			$\bigotimes_{i=1}^{2} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,57\frac{1}{2}}$	$\bigotimes_{i=1}^{2} \beta_{s_i}^{\text{l.o.}f_1} = \beta_{15,76\frac{2}{3}}$
D^{f_1}			$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_1} &= b^{f_1} \\ 15 \cdot [t - 57\frac{1}{2}]^+ &= 25 \\ t &= 59\frac{1}{6} \end{aligned}$	$\begin{aligned} \beta_{\text{e2e}}^{\text{l.o.}f_1} &= b^{f_1} \\ 15 \cdot [t - 76\frac{2}{3}]^+ &= 25 \\ t &= 78\frac{1}{3} \end{aligned}$
B^{f_1}			$\begin{aligned} \alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) &= 5 \cdot 57\frac{1}{2} + 25 \\ &= 312\frac{1}{2} \end{aligned}$	$\begin{aligned} \alpha^{f_1}(T_{\text{e2e}}^{\text{l.o.}f_1}) &= 5 \cdot 76\frac{2}{3} + 25 \\ &= 408\frac{1}{3} \end{aligned}$

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