RDMA Deadlock Analysis

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1 Analysis

See Figure 1 for the network topology and flow setup.

Assume a fluid model. Assume XON and XOFF threshold values are the same θ. Assume unit link capacity. Assume FIFO scheduling.

We can get the following equations for flow f.

$$\frac{d(S_f^1(t))}{dt} = \begin{cases} 1, & \text{if } S_f^1(t) - S_f^2(t) < \theta. \\ 0, & \text{if } S_f^1(t) - S_f^2(t) \geq \theta. \end{cases} \tag{1}$$

$$\frac{d(S_f^2(t))}{dt} = \begin{cases} \frac{S_f^1(t) - S_f^2(t)}{S_f^1(t) - S_f^2(t) + S_g^3(t) - S_g^4(t)}, & \text{if } S_f^2(t) - S_f^3(t) < \theta. \\ 0, & \text{if } S_f^2(t) - S_f^3(t) \geq \theta. \end{cases} \tag{2}$$

$$\frac{d(S_f^3(t))}{dt} = \begin{cases} 1, & \text{if } S_f^3(t) - S_f^4(t) < \theta \text{ and } S_f^2(t) - S_f^3(t) > 0. \\ 0, & \text{otherwise.} \end{cases} \tag{3}$$

Similarly, we can get $\frac{S_g^1(t)}{dt}$, $\frac{S_g^2(t)}{dt}$, $\frac{S_g^3(t)}{dt}$.

Additionally, we can have the following two equations.

$$\frac{d(S_f^2(t))}{dt} + \frac{d(S_g^4(t))}{dt} = \begin{cases} 1, & \text{if } S_f^2(t) - S_f^3(t) < \theta \text{ and } S_g^3(t) - S_g^4(t) > 0 \text{ and } S_f^1(t) - S_f^2(t) > 0. \\ \frac{S_f^2(t)}{dt}, & \text{if } S_f^2(t) - S_f^3(t) < \theta \text{ and } S_g^3(t) - S_g^4(t) = 0 \text{ and } S_f^1(t) - S_f^2(t) > 0. \\ \frac{S_g^4(t)}{dt}, & \text{if } S_f^2(t) - S_f^3(t) < \theta \text{ and } S_g^3(t) - S_g^4(t) > 0 \text{ and } S_f^1(t) - S_f^2(t) = 0. \\ 0, & \text{otherwise.} \end{cases} \tag{4}$$

$$\frac{d(S_g^2(t))}{dt} + \frac{d(S_f^4(t))}{dt} = \begin{cases} 1, & \text{if } S_g^2(t) - S_g^3(t) < \theta \text{ and } S_f^3(t) - S_f^4(t) > 0 \text{ and } S_g^1(t) - S_g^2(t) > 0. \\ \frac{S_g^2(t)}{dt}, & \text{if } S_g^2(t) - S_g^3(t) < \theta \text{ and } S_f^3(t) - S_f^4(t) = 0 \text{ and } S_g^1(t) - S_g^2(t) > 0. \\ \frac{S_f^4(t)}{dt}, & \text{if } S_g^2(t) - S_g^3(t) < \theta \text{ and } S_f^3(t) - S_f^4(t) > 0 \text{ and } S_g^1(t) - S_g^2(t) = 0. \\ 0, & \text{otherwise.} \end{cases} \tag{5}$$

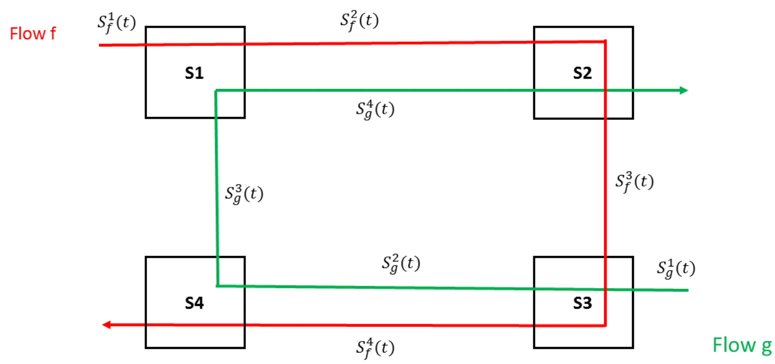

Figure 1: The scenario of four switches and two flows.

The initial conditions are $S_f^i(t) = 0$ for $i \in [0, 3]$ and $S_g^j(t)$ for $j \in [0, 3]$.

With the initial conditions, and 8 variables and 8 equations, in theory we should be able to calculate all the service curves.

Deadlock can occur if $\exists t_0 < \infty$, $\frac{S_f^i(t)}{dt} = 0$ and $\frac{S_g^j(t)}{dt} = 0$ for $t > t_0$. Deadlock cannot occur if no such t_0 exists.

2 A simple case for matlab study

$$\frac{d(S_f^1(t))}{dt} = \begin{cases} 1, & \text{if } S_f^1(t) - S_f^2(t) < \theta. \\ 0, & \text{if } S_f^1(t) - S_f^2(t) \geq \theta. \end{cases} \tag{6}$$

$$\frac{d(S_g^1(t))}{dt} = \begin{cases} 1, & \text{if } S_g^1(t) - S_g^2(t) < \theta. \\ 0, & \text{if } S_g^1(t) - S_g^2(t) \geq \theta. \end{cases} \tag{7}$$

$$\frac{d(S_f^2(t))}{dt} + \frac{d(S_g^2(t))}{dt} = 1 \tag{8}$$

$$\frac{d(S_f^2(t))}{dt} = \frac{S_f^1(t) - S_f^2(t)}{S_f^1(t) - S_f^2(t) + S_g^1(t) - S_g^2(t)} \tag{9}$$

Initial condition: $S_f^i(t) = 0$ and $S_g^i(t) = 0$.

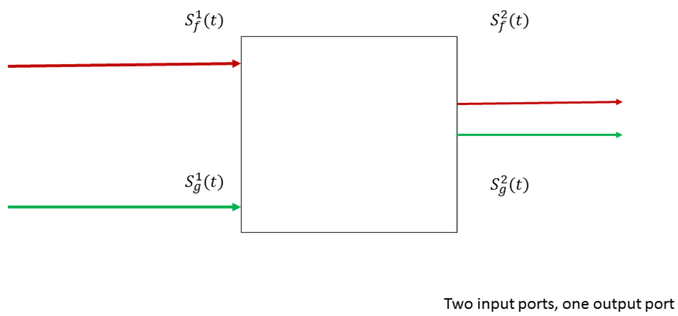

Figure 2: A simple case for matlab study.

3 A simple case with delay

$$\frac{d(S_g^0(t+d1))}{dt} = \begin{cases} 1, & \text{if } S_g^1(t) - S_g^2(t) < \theta. \\ 0, & \text{if } S_g^1(t) - S_g^2(t) \geq \theta. \end{cases} \tag{10}$$

$$\frac{d(S_f^2(t))}{dt} + \frac{d(S_g^2(t))}{dt} = 1 \tag{11}$$

$$\frac{d(S_f^2(t))}{dt} = \frac{S_f^1(t) - S_f^2(t)}{S_f^1(t) - S_f^2(t) + S_g^1(t) - S_g^2(t)} \tag{12}$$

$$S_f^0(t) = S_f^1(t+d0) \tag{13}$$

$$S_g^0(t) = S_g^1(t+d1) \tag{14}$$

Initial condition: $S_f^i(t) = 0$ and $S_g^i(t) = 0$. $S_f^1(t) = 0$ for $t < d0$, $S_g^0(t) = 0)$ for $t < d1$.

4 A second simple case

$$\frac{d(S_f^1(t))}{dt} = \begin{cases} 1, & \text{if } S_f^1(t) - S_f^2(t) < \theta \text{ and } S_f^0(t) - S_f^1(t) > 0. \\ 0, & \text{if } S_f^1(t) - S_f^2(t) \geq \theta. \end{cases} \tag{15}$$

$$\frac{d(S_g^1(t))}{dt} = \begin{cases} 1, & \text{if } S_g^1(t) - S_g^2(t) < \theta. \\ 0, & \text{if } S_g^1(t) - S_g^2(t) \geq \theta. \end{cases} \tag{16}$$

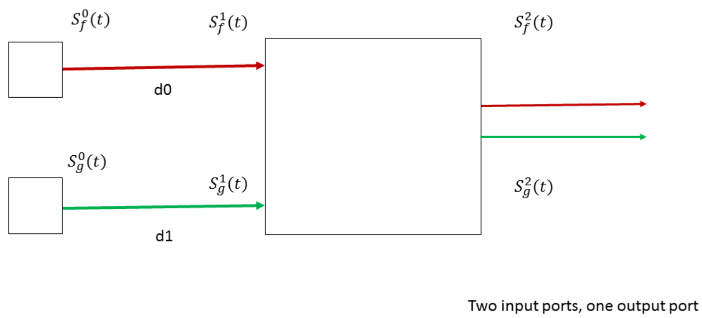

Figure 3: A simple case with link propagation delay.

$$\frac{d(S_f^2(t))}{dt} + \frac{d(S_g^2(t))}{dt} = 1 \tag{17}$$

Here we assume that $S_f^0(t)$ is known. For example $S_f^0(t) = 0.1t$. Also in this case we assume $S_f^0(t)$ cannot be paused, which means $S_f^0(t) - S_f^1(t) \leq B$, where B is the buffer size.

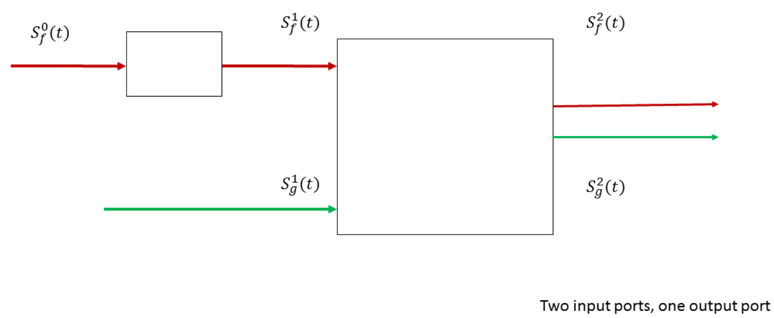

Figure 4: A second simple case.