HW Solutions #6

ELEN E4710 - Intro to Network Engineering | Due 12/6/2004
Fall 2004 | Prof. Rubenstein

Homework must be turned in at the beginning of class on the due date indicated above. CVN students have one additional day. Late assignments will not be accepted.

1. 3 flows, f_1, f_2, and f_3 all pass through the same router R. Packets from flows f_1 and f_2 arrive at R in bursts of 10 with a period of one second, packets from f_3 arrive at the router one at a time with a period of .1 seconds. Packets from all flows contain the the same number of bytes). Suppose packets from f_1 start arriving at R at time $t = 0$, flow f_2 at time $t = 5$, and flow f_3 at time $t = 0.5$. If each flow transmits a total of 100 packets, and the router processes a packet every 0.05 seconds, what are the completion times of the various flows when

   (a) R uses FIFO (FCFS) queueing? Ans)
   The last packet of f_1 is served in time interval $[11.45, 11.50)$.
   The last packet of f_2 is served in time interval $[15.20, 15.25)$.
   The last packet of f_3 is served in time interval $[13.20, 13.25)$.
   ∎

   (b) R uses round robin?
   Ans)
   The last packet of f_1 is served in time interval $[12.35, 12.40)$.
   The last packet of f_2 is served in time interval $[15.20, 15.25)$.
   The last packet of f_3 is served in time interval $[12.95, 13.00)$.
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   (c) R uses weighted fair queueing where the slack (i.e., the maximum reserve that a flow can build up) is 20 packets?
   Ans)
   The last packet of f_1 is served in time interval $[13.60, 13.65)$.
   The last packet of f_2 is served in time interval $[15.20, 15.25)$.
   The last packet of f_3 is served in time interval $[13.70, 13.75)$.
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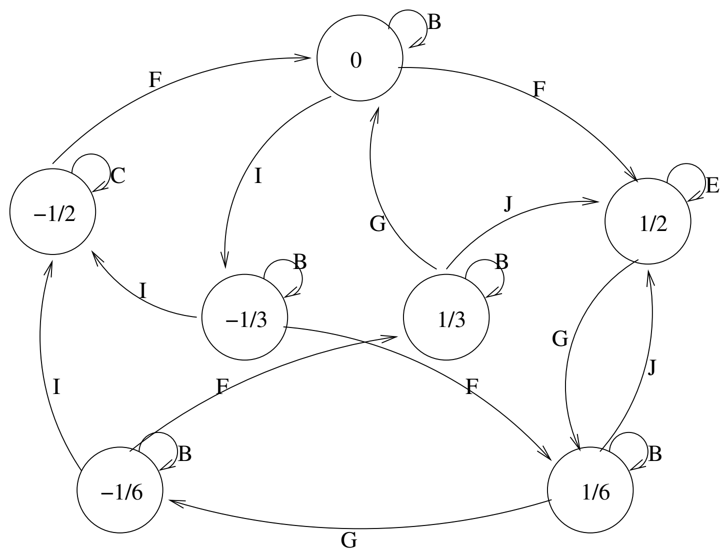
2. Construct a FSM for a router that implements weighted fair queueing for two flows f_1 and f_2 where $w_1 = 3, w_2 = 2$, and the slack is 0.5 (where the processing of a packet from f_1 adds $1/3$ to its virtual clock, and the processing of a packet from f_2 adds $1/2$ to its virtual clock). Your state machine can depend on the following functions and events to simplify its design:

   - $IE()$: the queue is empty (prior to an arrival)
   - $H(i)$: $H(i)$ equals 0 when no packets from f_i are queued in the system, and equals 1 otherwise
   - $D()$: triggered when the router completes processing its current packet.
   - $A(i)$: triggered when an arrival to the router from f_i occurs (only needs to be used when the router is not processing any packets).
   - $P(i)$: process a packet from flow f_i

   With these functions and events, you should build your FSM so that it indicates clearly whose packet should be processed next whenever such a decision needs to be made. (Hint: each state should indicate the current difference between the two flow's clocks.) Suggestion: You should create functions that combine the above functions, e.g., let $G(i) = (IE(), A(i))|(D(), H(i) = 1)$.

Ans) Define the following transition functions:

B: $D\&H(1) = 0\&H(2) = 0$ (system is empty)
C: $(D\&H(1) = 0) \;||\; ((IE()\&A(2))|P(2))$ (system is empty or serve f_2 when no packet from f_1)
E: $(D\&H(2) = 0) \;||\; ((IE()\&A(1))|P(1))$ (system is empty or serve f_1 when no packet from f_2)
F: $((D\&H(1) = 1) \;||\; (IE()\&A(1))) \mid P(1)$ (serve f_1 when the state is non-positive)
G: $((D\&H(2) = 1) \;||\; (IE()\&A(2))) \mid P(2)$ (serve f_2 when the state is positive)
I: $((D\&H(1) = 0\&H(2) = 1) \;||\; (IE()\&A(2))) \mid P(2)$ (serve f_2 when no packets from f_1)
J: $((D\&H(2) = 0\&H(1) = 1) \;||\; (IE()\&A(1))) \mid P(1)$ (serve f_1 when no packets from f_2)



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3. Construct a Markov model for a round-robin queueing system that can store up to 4 packets for processing, where no more than 2 packets from a single flow is ever stored. Assume there are two flows in the system , where both flow's packets are processed at rate μ, and flow f_i's packets arrive at rate λ_i. Label transistions with their transition probabilities.

   Ans)

   Define the state (i, j, k) when the system has i packets from f_1, j packets from f_2 and the last packet transmitted is from f_k.

   Because $0 \leq i, j \leq 2$ and $k = 1, 2$, we have 18 states.

   Except state $(0, 0, 1)$ and $(0, 0, 2)$, each state has a transition with rate μ. State $(i, j, 1)$ has the μ transition to state $(i, j-1, 2)$ if $j > 1$, and to state $(i-1, 0, 1)$ if $j = 0$. State $(i, j, 2)$ has the μ transition to state $(i-1, j, 1)$ if $i > 1$, and to state $(0, j-1, 2)$ if $i = 0$.

   Each state (i, j, k) has a transition with rate λ_1 to state $(i + 1, j, k)$ if $i < 2$ and a transition with rate λ_2 to state $(i, j + 1, k)$ if $j < 2$.

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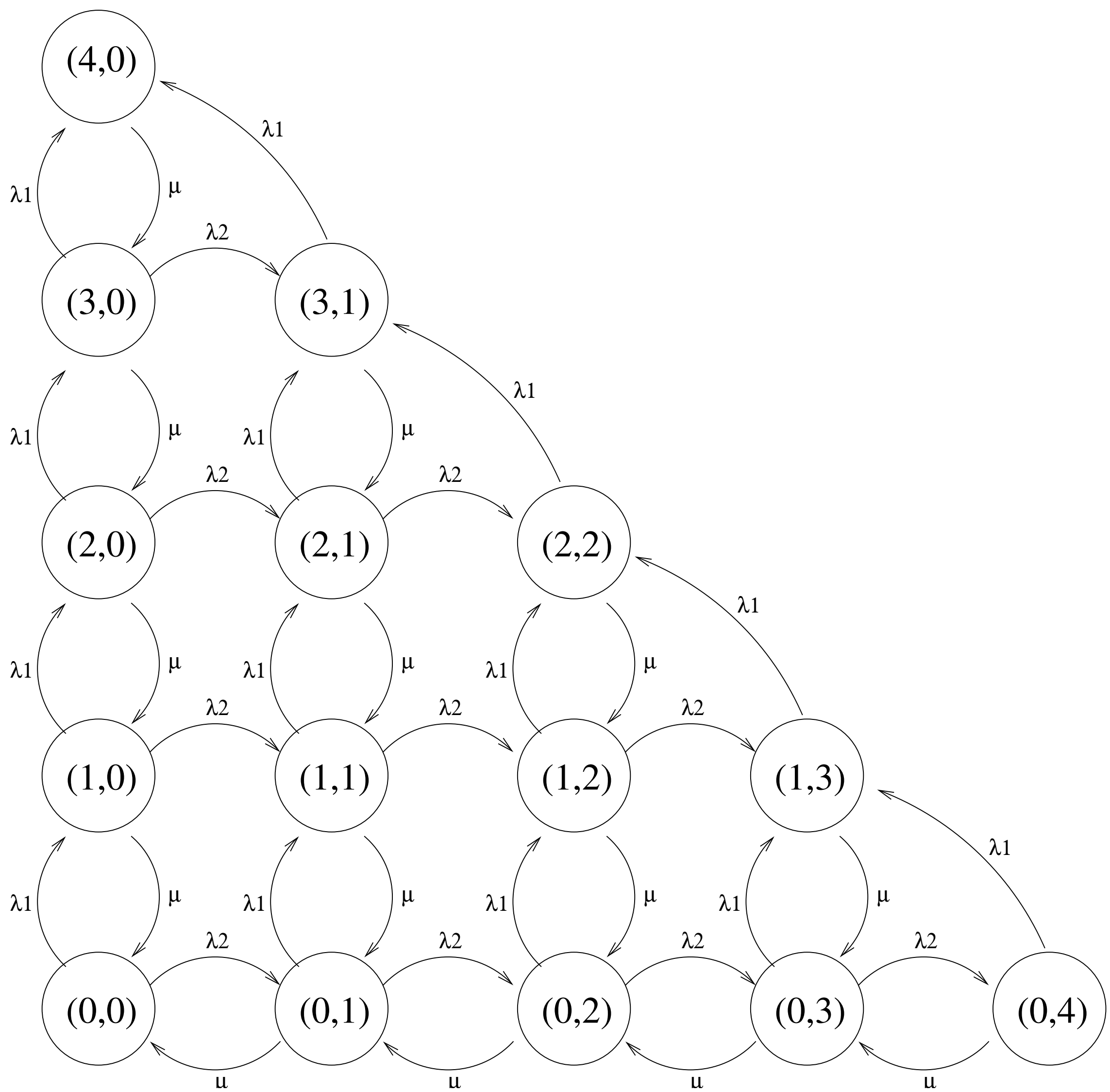
4. Construct Markov models for each of two priority queueing systems, each processing packets from two flows. Each system can hold a total of 4 packets in total. A packet from f_1 should always be processed before any packets from f_2 in the queue. Assume both flow's packets are processed at rate μ, and flow f_i's packets arrive at rate λ_i.

   (a) In the first system, a packet from f_1 arriving to a full queue will replace a packet in the queue from f_2 (if one exists).

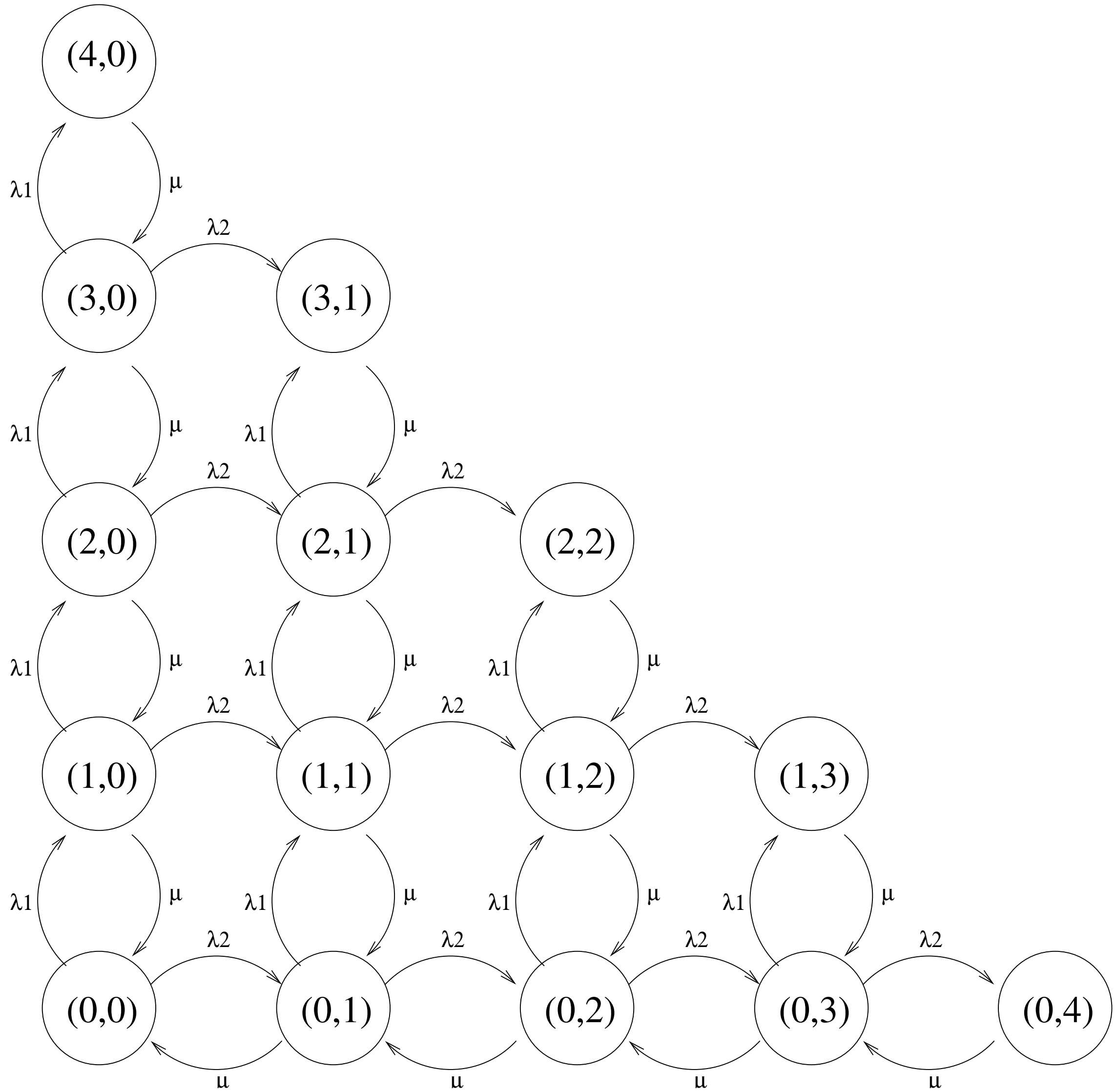
   Ans)

   Define the state to be (i, j) when the system has i packets from f_1 and j packets from f_2.



(b) In the second system, packets in the queue are not removed except when their processing is complete. Assume that a packet arriving from f_1 to a full queue will be turned away, even if there are packets from flow f_2 in the queue.

Ans)



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