Real Time System by Jane W. S. Liu Chapter 3.1 Solution

Q. 3.1: Because sporadic jobs may have varying release times and execution times, the periodic task model may be too inaccurate and can lead to undue under utilization of the processor even when the inter release times of jobs are bounded from below and their executions are bounded from above. As an example, suppose we have a stream of sporadic jobs whose inter release times are uniformly distributed from 9 to 11. Their execution times are uniformly distributed from 1 to 3.

a. What are the parameters of the periodic task if we were to use such a task to model the stream?

Solution:  http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu.html
Q.3.2: Consider the real-time program described by the pseudo code below. Names of jobs are in italic.

At 9 AM, start: have breakfast and go to office;
At 10 AM,
   if there is class,
      teach;
   Else, help students;
When teach or help is done, eat_lunch;
Until 2 PM, sleep;
If there is a seminar,
   If topic is interesting,
      listen;
   Else, read;
Else
   write in office;
When seminar is over, attend social hour;
discuss;
jog;

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_29.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_29.html)

Q.3.3: job_1 | job_2 denotes a pipe: The result produced by job_1 is incrementally consumed by job_2. (As an example, suppose that job_2 reads and displays one character at a time as each handwritten character is recognized and placed in a buffer by job_1.) Draw a precedence constraint graph to represent this producer-consumer relation between the jobs.

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_8405.html?spref=fb](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_8405.html?spref=fb)

Q.3.4: Draw a task graph to represent the flight control system described in Figure 1-3.

a) Assume the producers and consumers do not explicitly synchronize (i.e., each consumer uses the latest result generated by each of its producers but does not wait for the completion of the producer.)
Real Time System by Jane W. S. Liu Chapter 4.1 Solution

**Q.4.1:** The feasible interval of each job in the precedence graph in figure 4P-1 is given next to its name. The execution time of all jobs are equal to 1.

![Precedence Graph](image)

a) Find the effective release times and deadlines of the jobs in the precedence graph in Figure 4P-1.

**Solution** [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_9175.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_9175.html)

Real Time System by Jane W. S. Liu Chapter 4.2 Solution

**Q.4.2:** The execution times of the jobs in the precedence graph in figure 4P-2 are all equal to 1, and their release times are identical. Give a non preemptive optimal schedule that minimizes the completion time of all jobs on three processors. Describe briefly the algorithm you used to find the schedule.

![Precedence Graph](image)

**Solution** [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_4082.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_4082.html)
Real Time System by Jane W. S. Liu Chapter 4.4 Solution

Q.4.4: Consider a system that has five periodic tasks, A, B, C, D, and E, and three processors P₁, P₂, P₃. The periods of A, B, and C are 2 and their execution times are equal to 1. The periods of D and E are 8 and their execution times are 6. The phase of every task is 0, that is, the first job of the task is released at time 0. The relative deadline of every task is equal to its period.

a) Show that if the tasks are scheduled dynamically on three processors according to the LST algorithm, some jobs in the system cannot meet their deadlines.

Sol:

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_1862.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_1862.html)

Real Time System by Jane W. S. Liu Chapter 4.5 Solution

Q.4.5: A system contains nine non-preemptable jobs named Ji, for i = 1, 2, ..., 9. Their execution times are 3, 2, 2, 2, 4, 4, 4, 4, and 9, respectively, their release times are equal to 0, and their deadlines are 12. J₁ is the immediate predecessor of J₉, and J₄ is the immediate predecessor of J₅, J₆, J₇, and J₈. There are no other precedence constraints. For all the jobs, Ji has a higher priority than Jk if i < k.

a) Draw the precedence graph of the jobs.

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_6447.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_6447.html)

Real Time System by Jane W. S. Liu Chapter 4.7 Solution

Q.4.7: Consider the set of jobs in Figure 4-3. Suppose that the jobs have identical execution time. What maximum execution time can the jobs have and still can be feasible scheduling on one processor? Explain your answer.

![Graph of jobs](http://example.com/graph.png)

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_3971.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_3971.html)

Real Time System by Jane W. S. Liu Chapter 5.1(a)(b) Solution
Q.5.1: Each of the following systems of periodic tasks is scheduled and executed according to a cyclic schedule. For each system, choose an appropriate frame size. Preemptions are allowed, but the number of preemption should be kept small.

a) (6, 1), (10, 2), and (18, 2)

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_5855.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_5855.html)

Real Time System by Jane W. S. Liu Chapter 5.1(c)(d) Solution

Q5.1: Each of the following systems of periodic tasks is scheduled and executed according to a cyclic schedule. For each system, choose an appropriate frame size. Preemptions are allowed, but the number of preemptions should be kept small.

c) (4, 0.5), (5, 1.0), (10, 2), and (24, 9)

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_3069.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_3069.html)

Real Time System by Jane W. S. Liu Chapter 5.1(e)(f) Solution

Q5.1: Each of the following systems of periodic tasks is scheduled and executed according to a cyclic schedule. For each system, choose an appropriate frame size. Preemptions are allowed, but the number of preemptions should be kept small.

e) (5, 0.1), (7, 1.0), (12, 6), and (45, 9)

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_793.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_793.html)

Real Time System by Jane W. S. Liu Chapter 5.2 Solution

Q.5.2: A system uses the cyclic EDF algorithm to schedule sporadic jobs. The cyclic schedule of periodic tasks in the system uses a frame size of 5, and a major cycle contains 6 frames. Suppose that the initial amounts of slack time in the frames are 1, 0.5, 0.5, 0.5, 1, and 1.

a. Suppose that a sporadic job \( S(23, 1) \) arrives in frame 1, sporadic jobs \( S_2(16, 0.8) \) and \( S_3(20, 0.5) \) arrive in frame 2. In which frame are the accepted sporadic jobs scheduled?

Solution [http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_2408.html](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_2408.html)
Q.5.3: Draw a network flow graph that we can use to find a preemptive cyclic schedule of the periodic tasks

\[ T_1 = (3, 7, 1); \quad T_2 = (4, 1); \quad T_3 = (6, 2.4, 8). \]

Solution: [Link to solution](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_4437.html)

Q.5.4: A system contains the following periodic tasks:

\[ T_1 = (5, 1); \quad T_2 = (7, 1, 9); \quad T_3 = (10, 3) \text{ and } T_4 = (35, 7). \]

If the frame size constraint (5-1) is ignored, what are the possible frame sizes?

Solution: [Link to solution](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_8734.html)

Q.6.4: A system contains periodic tasks: (8, 1), (15, 3), (20, 4), and (22, 6). Its total utilization is 0.80. Construct the initial segment in the time interval (0, 50) of a rate-monotonic schedule of the system.

Solution: [Link to solution](http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_1931.html)

Q.6.5: Which of the following systems of periodic tasks are schedulable by the rate-monotonic algorithm? By the earliest-deadline-first algorithm? Explain your answer.

a. \[ T = \{(8, 3), (9, 3), (15, 3)\} \]

Solution: [Link to solution](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6564.html)
Real Time System by Jane W. S. Liu Chapter 6.8 Solution

Q.6.8: a) Use the time demand analysis method to show that the rate-monotonic algorithm will produce a feasible schedule of the tasks (6,1), (8,2) and (15,6).

Solution [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6444.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6444.html)

Real Time System by Jane W. S. Liu Chapter 6.6 Solution

Q.6.6: Give two different explanation of why the periodic tasks (2,1), (4,1) and (8,2) are schedulable by the rate monotonic algorithm.

Solution [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2.html)

Real Time System by Jane W. S. Liu Chapter 6.7 Solution

Q.6.7: This problem is concerned with the performance an behavior of rate-monotonic an earliest-deadline-first algorithms.

a. Construct the initial segments in the time interval (0, 750) of a rate-monotonic schedule and an earliest-deadline-first schedule of the periodic tasks (100, 20) (150, 50), and (250, 100) whose total utilization is 0.93.

Solution [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_714.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_714.html)

Real Time System by Jane W. S. Liu Chapter 6.9 Solution

Q.6.9: The Periodic Tasks (3,1), (4,2), (6,1) are scheduled according to the rate-monotonic algorithm.

a) Draw Time Demand Function of the tasks

Solution [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_4718.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_4718.html)

Real Time System by Jane W. S. Liu Chapter 6.10 Solution

Q.6.10: Which of the following fixed-priority task is not schedulable? Explain your answer.
Real Time System by Jane W. S. Liu Chapter 6.11 Solution

Q.6.11: Find the maximum possible response time of tasks T4 in the following fixed-priority system by solving the equation w4(t) = t, iteratively

\[ T1 = (5,1), \quad T2 = (3,1), \quad T3 = (7,2.5), \quad \text{and} \quad T4 = (16,1) \]

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_3.html

Real Time System by Jane W. S. Liu Chapter 6.13 Solution

Q.6.13: Find the length of an in-phase level-3 busy interval of the following fixed-priority tasks:

\[ T1 = (5, 1), \quad T2 = (3,1), \quad T3 = (8, 1.6), \quad \text{and} \quad T4 = (18, 3.5) \]

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6263.html

Real Time System by Jane W. S. Liu Chapter 6.15 Solution

Q.6.15: A system consists of three periodic tasks: (3, 1), (5, 2), and (8, 3).

a. What is the total utilization?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_9426.html

Real Time System by Jane W. S. Liu Chapter 6.21 Solution
Q.6.21: a) Use the time-demand analysis method to show that the set of periodic tasks \{(5, 1), (8, 2), (14, 4)\} is schedulable according to the rate-monotonic algorithm.

Solution  http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_1209.html

Real Time System by Jane W. S. Liu Chapter 6.23 Solution

Q.6.23: A system contains tasks T1 = (10,3), T2 = (16,4), T3 = (40,10) and T4 = (50,5). The total blocking due to all factors of the tasks are b1 = 5, b2 = 1, b3 = 4 and b4 = 10, respectively. These tasks are scheduled on the EDF basis. Which tasks (or task) are (or is) schedulable? Explain your answer.

Solution  http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_5.html

Real Time System by Jane W. S. Liu Chapter 6.31 Solution

Q.6.31: Interrupts typically arrive sporadically. When an interrupt arrives, interrupt handling is serviced (i.e., executed on the processor) immediately and in a nonpreemptable fashion. The effect of interrupt handling on the schedulability of periodic tasks can be accounted for in the same manner as blocking time. To illustrate this, consider a system of four tasks: T1 = (2.5, 0.5), T2 = (4, 1), T3 = (10, 1), and T4 = (30, 6). Suppose that there are two streams of interrupts. The interrelease time of interrupts in one stream is never less than 9, and that of the other stream is never less than 25. Suppose that it takes at most 0.2 units of time to service each interrupt. Like the periodic tasks interrupt handling tasks (i.e., the stream of interrupt handling jobs) are given fixed priorities. They have higher priorities than the periodic tasks, and the one with a higher rate (i.e., shorter minimum interrelease time) has a higher priority.

a. What is the maximum amount of time each job in each periodic task may be delayed from completion by interrupts?

Solution  http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_3964.html
**Real Time System by Jane W. S. Liu Chapter 7.1 Solution**

**Q.7.1:** A system contains three periodic tasks. They are \((2.5,1)\), \((4,0.5)\), \((5,0.75)\), and their total utilization is 0.475.

a) The system also contains a periodic server \((2,0.5)\). The server is scheduled with the periodic tasks rate-monotonically.

1) Suppose that the periodic server is a basic sporadic server. What are the response time of the following two aperiodic jobs: One arrives at 3 and has execution time 0.75, and one arrives at 7.5 and has execution time 0.6.

**Solution** [Link](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6.html)

---

**Real Time System by Jane W. S. Liu Chapter 7.2 Solution**

**Q.7.2:** A system contains three periodic tasks. They are \((3,1)\), \((4,0.5)\), \((5,0.5)\). The task system also contains a sporadic server whose period is 2. The sporadic server is scheduled with the periodic tasks rate-monotonically. Find the maximum utilization of the server if all deadlines of periodic tasks are surely met.

1) Suppose that the server in part (a) is a pure polling server. What are the response time of the following two aperiodic jobs: one arrives at 2.3 and has execution time 0.8, and one arrives at 12.7 and has execution time 0.6?

**Solution** [Link](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2439.html)

---

**Real Time System by Jane W. S. Liu Chapter 7.3 Solution**

**Q.7.3:** Consider a system containing the following periodic tasks: \(T_1 = (10,2)\), \(T_2 = (14,3)\), \(T_3 = (21,4)\). A periodic server of period 8 is used to schedule aperiodic jobs.

a) Suppose that the server and the tasks are scheduled rate-monotonically.

1) If the periodic server is a deferrable server, how large can its maximum execution budget be?

**Solution** [Link](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_7.html)

---

**Real Time System by Jane W. S. Liu Chapter 7.4 Solution**
Q. 7.4: Consider a system that contains two periodic tasks $T_1 = (7,2)$ and $T_2 = (10,3)$. There is a bandwidth preserving server whose period is 6. Suppose that the periodic tasks and the server are scheduled rate-monotonically.

a) Suppose that the server is deferrable server.

1) What is the maximum server size?


Real Time System by Jane W. S. Liu Chapter 7.5 Solution

Q. 7.5: Suppose that the periodic tasks in the previous problem are scheduled along with a server on the earliest deadline first basis.

a) What is the maximum server size if the server is a deferrable server? Is this size a function of the period of the server? If not, why not? If yes, what is the best choice of server size?

b) What is maximum server size if the server is a total bandwidth server?

Solution [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_5481.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_5481.html)

Real Time System by Jane W. S. Liu Chapter 7.19 Solution

Q. 7.19: Davis et al., suggested a dual priority scheme for scheduling aperiodic jobs in the midst of periodic tasks. According to dual priority scheme, the system keeps three bands of priority, each containing one or more priority levels. The highest band contains real time priorities; they are for hard real time tasks. Real time priorities are assigned to hard real time tasks according to some fixed priority scheme. The middle priority band is for aperiodic jobs. The lowest priority band is also hard real time tasks. Specifically, when jobs $J_{i,k}$ in a periodic task $T_i = (p_i, e_i, D_i)$ is released, it has a priority in the lowest priority band until its priority promotion time. At its priority promotion time, its priority is raised to its real time priority. Let $W_i$ denote the maximum response time of all jobs in $T_i$ when they execute at the real time priority of the task. The priority promotion time of each job is $Y_i = D_i - W_i$ from its release time. Since $W_i$ can be computed off line or at admission control time, the release promotion time $Y_i$ for jobs in each tasks $T_i$ needs to be computed only once. By delaying as much as possible the scheduling of every hard real time jobs at its real time priority, the scheduler automatically creates slacks for aperiodic jobs.
a) Give an intuitive argument to support the claim that this scheme will not cause any periodic job to miss its deadline if the system of periodic tasks is schedulable.

**Solution** [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu.html)

Real Time System by Jane W. S. Liu Chapter 7.23 Solution

**Q.7.23:** Suppose that the intervals between arrivals of sporadic jobs are known to be in the range \((a,b)\). The execution time of each sporadic job is at most \(e \leq a\) units. Suppose relative deadlines of sporadic jobs are equal to \(a\). You are asked to design a bandwidth preserving server that will be scheduled rate monotonically with other periodic tasks. Sporadic jobs waiting to be completed are executed on the first in first out basis in the time intervals where the periodic server is scheduled. Choose the period and utilization of this server so that all sporadic jobs will be completed by their deadlines and the utilization of the sporadic server is as small as possible.


Real Time System by Jane W. S. Liu Chapter 8.1 Solution

**Q.8.1:** A system contains five jobs. There are three resources \(X\), \(Y\) and \(Z\). The resources required of the jobs are listed below.

\[
\begin{align*}
J_1 & : [X;2] \\
J_2 & : \text{NONE} \\
J_3 & : [Y;1] \\
J_4 & : [X;3 [Z;1]] \\
J_5 & : [Y;4 [Z;2]]
\end{align*}
\]

The priority \(J_i\) is higher than the priority of \(J_j\) for \(i < j\). What are the maximum blocking times of the jobs under the nonpreemptable critical section protocol and under the priority ceiling protocol?

**Solution** [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_10.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_10.html)
Real Time System by Jane W. S. Liu Chapter 8.2 Solution

Q.8.2: A system contains the following four periodic tasks. The tasks are scheduled by the rate monotonic algorithm and the priority ceiling protocol.

- $T_1 = (3, 0.75)$, $b_1 = 0.9$
- $T_2 = (3.5, 1.5)$, $b_2 = 0.75$
- $T_3 = (6, 0.6)$, $b_3 = 0.9$
- $T_4 = (10, 1)$

$b_i$ is the blocking time of $T_i$. Are the tasks schedulable? Explain your answer.

Solution [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_1120.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_1120.html)

Real Time System by Jane W. S. Liu Chapter 8.3 Solution

Q.8.3: Consider a fixed priority system in which there are five tasks $T_i$, for $i = 1, 2, 3, 4$ and 5, with decreasing priorities. There are two resources $X$ and $Y$. The critical sections of $T_1$, $T_2$, $T_4$ and $T_5$ are $[Y;3]$, $[X;4]$, $[Y;5 \{X;2\}]$ and $[X;10]$ respectively. (Note that $T_3$ does not require any resource.) Find the blocking time $b_{i(rc)}$ of the tasks.

Solution [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2315.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2315.html)

Real Time System by Jane W. S. Liu Chapter 8.7 Solution

Q.8.7: A system contains the following five periodic tasks. The tasks are scheduled rate monotonically.

- $T_1 = (6, 3, [X;2])$
- $T_2 = (20, 5, [Y;2])$
- $T_3 = (200, 5, [X;3 \{Z;1\}])$
- $T_4 = (210, 6, [Z;5 \{Y;4\}])$

Compare the schedulability of the system when the priority ceiling protocol is used versus the NPCS protocol.

Q.8.10: Given a system consisting of the following tasks whose periods, execution times and resource requirements are given below.

\[
\begin{align*}
T_1 &= (2, 0.4, [X, 3; 0.3]) \\
T_2 &= (3, 0.75, [X, 1; 0.3][Y, 1; 0.4]) \\
T_3 &= (6, 1.0, [Y, 1; 0.4][Z, 1; 0.5 [X, 1; 0.4]]) \\
T_4 &= (8, 1.0, [X, 1; 0.5][Y, 2; 0.1] [Z, 1; 0.4])
\end{align*}
\]

There are 3 units of X, 2 units of Y and 1 unit of Z. The tasks are scheduled by EDF algorithm and the stack based protocol.

a) Find the preemption ceiling of each resource and the maximum blocking time for each task.

**Solution** [http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_12.html](http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_12.html)