CprE 458/558: Real-Time Systems

Iowa State University
Final Homework 75 points

1. **Chapter 4**, Questions 1-5, Pages 128-129, Reading assignment.

2. (4 points) Question 10.

3. (4 points) Question 11.

4. (6 points) For the task set given in the table, answer the following. Assume tasks are independent. Assume two copies \(Pr_t\) and \(Bk_i\) for each task \(T_t\). Assume a multiprocessor system with 6 processors. Use EDF (Earliest Deadline First) as the base scheduling algorithm.

<table>
<thead>
<tr>
<th>task</th>
<th>comp. time</th>
<th>deadline</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T_1 \cdots T_6)</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>(T_7 \cdots T_{12})</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>(T_{13} \cdots T_{18})</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>(T_{19} \cdots T_{24})</td>
<td>20</td>
<td>110</td>
</tr>
</tbody>
</table>

(a) Construct schedule using no overloading.
(b) Construct schedule using full overloading (i.e., all the 6 processors are in a single group).
(c) Construct schedule using static grouping assuming each group has 3 processors.

The backup copy of a task is considered for scheduling immediately following its primary copy.

When scheduling a backup copy, overload it with the best possible backup if possible. To overload on a processor at a given moment, consider the backup that is scheduled last on that processor.

A task \(T_t\) is said to be feasible in the schedule, only if both primary and backup copies of it are feasible in the schedule. If the primary or backup of a copy is not schedulable before its deadline, then the task is said to be rejected.

For each case (a)-(c), what is the guarantee ratio. Guarantee ratio is defined as the number of tasks feasibly scheduled to the number of tasks considered. Here, the number of tasks considered is 24.

5. \((m,k)\)-firm deadline model (3 points).

   Draw the state diagram for a periodic task with \((1,3)\)-firm guarantee requirement. Label the transitions. Identify the failure states.

   States are denoted by \(k\)-letter strings (3-letter strings in this case). The letters \(M\) and \(m\) are used to represent a **meeting** and a **missing** of deadline of a task instance, respectively.
<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>Packets Sent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1: Transmission schedule

For example, \( MMM \) denotes the state where the most recent instance of the task missed its deadline and the two before that met their deadlines. Starting from a state, the task makes a transition to one of two states, depending on whether its next instance meets (denoted by \( M \)) or misses (denoted by \( m \)) its deadline. For example, if the task is currently in state \( MMM \) and its next instance meets the deadline, then the task transits to state \( MM \). Label the transitions as \( M \) or \( m \).

Failure (i.e., timing failure) states are those states in which the number of “misses” is more than \( k - m \).

6. **Chapter 5**: Page 163: Questions 4, 6, 7, 9, 10 (2 points each).

7. **Chapter 6**: Page 198: Questions 3, 4 (2 points each).

8. (2 points) What are the advantages of path-based paradigm over task-based paradigm?

9. (2 points) Identify the “paths” and their characteristics (i.e., path name, path type, any other parameters) for the robotic application described in Homework 1.

10. **Chapter 7**: Reading assignment: Questions 1, 4, 7, channel setup issues.

11. (2.5 points) Compute the max-min fair allocation for sources A, B, C, D, and E, when their demands are 2, 3, 4, 4, and 5, respectively and the resource capacity is 15.

12. (2.5 points) Repeat the same for weighted max-min fair allocation assuming weights of the sources being 1.5, 0.5, 2.5, 1, and 2, respectively.

13. (5 points) The transmission schedule (Table 1) for a given flow lists for each second the number of packets sent between that time and the following second. The flow must stay within the bounds of a token bucket policer. What bucket depth does the flow need for the following token rates: (a) 2 packets per second; (b) 4 packets per second. Assume the bucket is initially full.


15. (5 points) Consider three connections (C1, C2, C3) share the output link, with each connection having an average inter-arrival time of 3 time units. Refer to Figure 7.12 (book: page 230) for the actual arrival pattern of packets from these connections. Show the schedule produced by the WFQ scheduler. Assume all packets are equal size.
16. **Chapter 10:** (2 points) Mention the limitations of 802.3, 802.4, and 802.5 protocols for real-time communication (2 points).

17. (6 points) Perform collision resolution using DCR-P protocol for the tree shown in Figure 10.5 (page 366) assuming all the **even numbered nodes** have a message to transmit. You need to show the channel status during collision resolution (by a 3-tuple shown on the top and right of each node) similar to what is shown in Figure 10.5 (6 points).

18. (6 points) Discuss the working of VTCSMA-L protocol for the messages shown in Figure 10.3 (page 359) with $\eta = 3$. In other words, use columns 1-4 of the figure and you need to fill in column 5 assuming $\eta = 3$. At a given time if more than one node is eligible for transmission, resolve the collision by favoring the node with smaller node-id instead of using probabilistic collision resolution (6 points).

19. (6 points) Collision resolution using DOD-P protocol for the following tree with 31 nodes with the following data (6 points).

- Number of message equivalence classes is 4.
- k-th message class is mapped onto the k-th element in the preorder search sequence of the time tree.
- Preorder search sequence of time tree is: 1, 2, 3, 4.
- Assume that all leaf nodes have a message to transmit.
- Assume following message equivalence classes: Message of nodes 16, 20, 24, 28 are mapped to message class 1; message of nodes 17, 21, 25, 29, are mapped to message class 2; message of nodes 18, 22, 26, 30 are mapped to class 3; message of nodes 19, 23, 27, 31 are mapped to class 4.
- Assume that these message classes do not change with time, i.e., message class recomputation is not required.

![DCR tree](image)

Show the working of the DoD-P protocol in the form of 4-tuple: \( < p, q, r, s > \) where

- \( p \): time slot number;
- \( q \): channel status (w: idle; c: collision, x: transmission),
- \( r \): node-id if successful transmission;
- \( s \): tree type (TIME: time tree, DCR: DCR tree).

For example, \( < 4, c, -, DCR > \) denotes at time slot 4, occurrence of collision in the DCR tree traversal. (DCR tree search is also known as static tree search).

20. Reading Assignment: FDDI (Fiber Distributed Data Interface) protocol.

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