CSIE 5452, Fall 2022: Quiz 1 Solution

Due at 3:30pm; Marked as Last Submission after 3:30pm; Gradescope Closed at 3:40pm

There are totally 50 points. You are expected to use X minutes for a question with X points. When you submit your solutions on Gradescope, please select the corresponding page(s) of each question.

1 CAN Timing Analysis (12pts)

Given a set of periodic messages μ_0, μ_1, μ_2 with their priorities, transmission times, and periods as follows:

Message	Priority (P_i)	Transmission Time (C_i) (msec)	Period (T_i) (msec)
μ_0	0	10	40
μ_1	1	30	100
μ_2	2	20	70

The worst-case response time R_i of μ_i can be computed as

$$R_i = Q_i + C_i, \tag{1}$$

and

$$Q_i = B_i + \sum_{\forall j, P_j < P_i} \left\lceil \frac{Q_i + \tau}{T_j} \right\rceil C_j, \tag{2}$$

where $\tau = 0.1$ (msec), Q_i is the worst-case waiting time of μ_i, B_i is the maximum blocking time of μ_i, which is equal to the maximum transmission time of all lower or same (μ_i itself) priority messages. The following tables are for your calculation, and they do not imply that there are exactly 3 iterations.

1. (6pts) What is the worst-case response time of μ_1?

   Answer: Q_1 is computed as follows:

Iteration	LHS (Q_1)	B_1	j	$Q_1 + \tau$	T_j	$\left\lceil \frac{Q_1+\tau}{T_j} \right\rceil$	C_j	RHS	Stop?
1	30	30	0	30.1	40	1	10	40	No
2	40	30	0	40.1	40	2	10	50	No
3	50	30	0	50.1	40	2	10	50	Yes

   $R_1 = Q_1 + C_1 = 50 + 30 = 80$ (msec).

2. (6pts) What is the worst-case response time of μ_2?

   Answer: Q_2 is computed as follows:

Iteration	LHS (Q_2)	B_2	j	$Q_2+\tau$	T_j	$\left\lceil \frac{Q_2+\tau}{T_j} \right\rceil$	C_j	RHS	Stop?
1	20	20	0	20.1	40	1	10	60	Yes
			1		100	1	30		(Constraint Violation)

The RHS is 60, and $60 + C_2 = 60 + 20 = 80 > T_2 = 70$. Therefore, the timing analysis returns a constraint violation (or infinity).

2 TDMA Timing Analysis (12pts)

Follow the assumptions (each time slot has the same length, each time slot serves exactly one frame, and a frame is transmitted only if the whole time slot is available) in the lecture and Homework 1. Answer the following questions for the "asynchronous" message with the following frame arrival pattern and the schedule pattern, based on the last digit of your student ID number, D. EXCEPT the last question, no explanation is required.

- If D is 0 or 5 or an alphabet, the frame arrival pattern is $(2, 5, 0, 2)$ and the schedule pattern is $(4, 10, 1, 4, 6, 7)$.
- If D is 1 or 6, the frame arrival pattern is $(2, 5, 1, 4)$ and the schedule pattern is $(4, 10, 1, 2, 6, 9)$.
- If D is 2 or 7, the frame arrival pattern is $(2, 5, 0, 3)$ and the schedule pattern is $(4, 10, 2, 5, 7, 8)$.
- If D is 3 or 8, the frame arrival pattern is $(2, 5, 2, 4)$ and the schedule pattern is $(4, 10, 0, 4, 7, 9)$.
- If D is 4 or 9, the frame arrival pattern is $(2, 5, 1, 3)$ and the schedule pattern is $(4, 10, 0, 2, 3, 7)$.

1. (1pt) Write down the last digit of your student ID number.

   Answer:

2. (1pt) Duplicate the arrival pattern (hint: $(4, 10, W, X, Y, Z)$).

   Answer:

   - $(4, 10, 0, 2, 5, 7)$.
   - $(4, 10, 1, 4, 6, 9)$.
   - $(4, 10, 0, 3, 5, 8)$.
   - $(4, 10, 2, 4, 7, 9)$.
   - $(4, 10, 1, 3, 6, 8)$.

3. (1pt) Duplicate the arriving times of frames in the frame arrival pattern but fix $m = 4$ and $p = 10$.

   Answer:

   - $(4, 10, 0, 2, 5, 7, 10, 12, 15, 17)$.
   - $(4, 10, 1, 4, 6, 9, 11, 14, 16, 19)$.
   - $(4, 10, 0, 3, 5, 8, 10, 13, 15, 18)$.
   - $(4, 10, 2, 4, 7, 9, 12, 14, 17, 19)$.
   - $(4, 10, 1, 3, 6, 8, 11, 13, 16, 18)$.

4. (1pt) Duplicate the starting times of time slots in the schedule pattern but fix $n = 4$ and $q = 10$.

   Answer:

   - $(4, 10, 1, 4, 6, 7, 11, 14, 16, 17)$.
   - $(4, 10, 1, 2, 6, 9, 11, 12, 16, 19)$.
   - $(4, 10, 2, 5, 7, 8, 12, 15, 17, 18)$.
   - $(4, 10, 0, 4, 7, 9, 10, 14, 17, 19)$.
   - $(4, 10, 0, 2, 3, 7, 10, 12, 13, 17)$.

5. (4pts) Complete the following table.

   Answer:

k	$\max_{1\le j\le n}(s_{j+k} - s_j)$	=	$\min_{1\le i\le m}(a_{i+k-1} - a_i)$	=	(Column-3) − (Column-5)
1	$\max_{1\le j\le 4}(s_{j+1} - s_j)$	4	$\min_{1\le i\le 4}(a_i - a_i)$	0	4
2	$\max_{1\le j\le 4}(s_{j+2} - s_j)$	7	$\min_{1\le i\le 4}(a_{i+1} - a_i)$	2	5
3	$\max_{1\le j\le 4}(s_{j+3} - s_j)$	9	$\min_{1\le i\le 4}(a_{i+2} - a_i)$	5	4
4	$\max_{1\le j\le 4}(s_{j+4} - s_j)$	10	$\min_{1\le i\le 4}(a_{i+3} - a_i)$	7	3

6. (4pts) Explain the scenario that the worst-case happens (which frame misses which time slot, and which frame suffers the worst case).

   Answer:

   - The first (whose arrival time is "0") misses the fourth time slot (whose starting time is "7"), and the second frame (whose arrival time is "2") suffers the worst case. When the first frame's arrival time is aligned with the fourth time slot's starting time (shifting "0" to "7"), the second frame arrives at "9" (shifting "2" to "9") and is served at "14", so the waiting time is 5.
   - The second (whose arrival time is "4") misses the second time slot (whose starting time is "2"), and the third frame (whose arrival time is "6") suffers the worst case. When the second frame's arrival time is aligned with the second time slot's starting time (shifting "4" to "2"), the third frame arrives at "4" (shifting "6" to "4") and is served at "9", so the waiting time is 5.
   - The second (whose arrival time is "3") misses the fourth time slot (whose starting time is "8"), and the third frame (whose arrival time is "5") suffers the worst case. When the second frame's arrival time is aligned with the fourth time slot's starting time (shifting "3" to "8"), the third frame arrives at "10" (shifting "5" to "10") and is served at "15", so the waiting time is 5.
   - The first (whose arrival time is "2") misses the first time slot (whose starting time is "0"), and the second frame (whose arrival time is "4") suffers the worst case. When the first frame's arrival time is aligned with the first time slot's starting time (shifting "2" to "0"), the second frame arrives at "2" (shifting "4" to "2") and is served at "7", so the waiting time is 5.
   - The first (whose arrival time is "1") misses the third time slot (whose starting time is "3"), and the second frame (whose arrival time is "3") suffers the worst case. When the first frame's arrival time is aligned with the third time slot's starting time (shifting "1" to '3"), the second frame arrives at "5" (shifting "3" to "5") and is served at "10", so the waiting time is 5.

3 Short Answers (12pts)

1. (4pts) This is the equation for the CAN timing analysis:

$$Q_i = B_i + \sum_{\forall j, P_j < P_i} \left\lceil \frac{Q_i + \tau}{T_j} \right\rceil C_j. \tag{3}$$

   If we replace B_i by "the largest transmission time of ALL messages", can the timing analysis still be used to guarantee that a message will respond before its analyzed worst-case response time? Explain the reason.

   Answer: Yes. It is more pessimistic, but pessimism, implying overestimation, is fine.

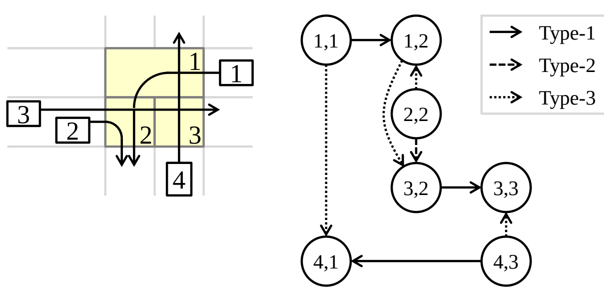
2. (4pts) There are two approaches to deal with constraint violations in simulated annealing. The first one adds a large constant M to the solution cost if the solution is not feasible, and the second one adds a large constant M to the solution cost for "each" constraint violation, *i.e.*, if there are eight violations, the first one adds M, and the second one adds $8M$. Which approach is better? Explain the reason.

   Answer: The first one is better because there is a lower risk of overflow, or the second one is better because it differentiates the numbers of constraint violations and tends to decrease the number of constraint violations.

3. (4pts) Regarding the graph-based intersection management, we can model an intersection as a set of conflict zones. List one advantage and one disadvantage if we use "fewer" conflict zones to model an intersection.

   Answer: Less expressiveness (resulting in less solution quality) but lower computational overhead.

4 Intersection Management (14pts)



An intersection scenario is given in the left figure. One example solution which describes the passing orders is given in the right figure. The example solution has no deadlock (a deadlock means that no vehicle can enter its next conflict zone or leave the intersection). However, having no deadlock is actually based on the assumption that all vehicles follow the passing orders. Now, different from the lecture, we have the following assumptions:

- Assumption 1: Vehicle 3 is not controllable (for example, not connected and not autonomous) so that it may NOT follow the passing orders with other vehicles.
- Assumption 2: Each pair of Vehicles 1, 2, and 4 still follows the corresponding passing order of the pair.

- Assumption 3: Same-lane overtaking is not allowed.

1. (6pts) Regarding the intersection scenario and the new assumptions, explain why the example solution may have a deadlock now.

   Answer: If Vehicle 3 enters Conflict Zone 2 before Vehicle 1 (the edge from $(1, 2)$ to $(3, 2)$ is reversed), then there is a deadlock.

2. (8pts) Regarding the intersection scenario and the new assumptions, is it possible to have other solutions which guarantee to have no deadlock?

   - If yes, (1) show one solution which guarantees to have no deadlock and (2) derive all the conditions (for example, Vehicle X enters Conflict Zone Z before Vehicle Y) which guarantee to have no deadlock.
   - If no, prove it.

   Answer: Yes. (1) One solution is to reverse the edge from $(1, 2)$ to $(2, 2)$ from the example solution. Vehicle 3 is "blocked" by Vehicle 2, so that Vehicle 3 can only enter the intersection after Vehicles 1 and 2 leave the intersection and cannot create a deadlock. (2) Vehicle 1 enters Conflict Zone 2 before Vehicle 2 OR Vehicle 4 enters Conflict Zone 1 before Vehicle 1.