CSIE 5452, Fall 2020 — Midterm Solution

Name: ____________________ SID: ____________________ Email: ____________________

1 CAN Timing Analysis (12pts)

Given a set of periodic messages $\mu_0, \mu_1, \mu_2, \mu_3$ 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	80
μ_1	1	40	100
μ_2	2	30	200
μ_3	3	20	400

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

$$R_i = Q_i + C_i,$$

and

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

where $\tau = 0.1$, 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. Perform the timing analysis for μ_2 by completing the following table (no explanation is required) and answering R_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	30	30	0	30.1	80	1	10	80	No
			1		100	1	40		
2	80	30	0	80.1	80	2	10	90	No
			1		100	1	40		
3	90	30	0	90.1	80	2	10	90	Yes
			1		100	1	40		

$R_2 = Q_2 + C_2 = 90 + 30 = 120$ (msec).

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 and answer the following questions for the "asynchronous" message with the frame arrival pattern $(2, 6, 0, 2)$ and the schedule pattern $(5, 12, 1, 2, 3, 8, 11)$. EXCEPT the last question, no explanation is required.

1. (2pts) Duplicate the arrival pattern (hint: $(4, 12, 0, 2, \ldots)$).

   Answer: $(4, 12, 0, 2, 6, 8)$.

2. (1pt) Duplicate the arriving times of frames in the frame arrival pattern but fix $m = 4$ and $p = 12$.

   Answer: $(4, 12, 0, 2, 6, 8, 12, 14, 18, 20)$.

3. (1pt) Duplicate the starting times of time slots in the schedule pattern but fix $n = 5$ and $q = 12$.

   Answer: $(5, 12, 1, 2, 3, 8, 11, 13, 14, 15, 20, 23)$.

4. (4pts) Complete the following table.

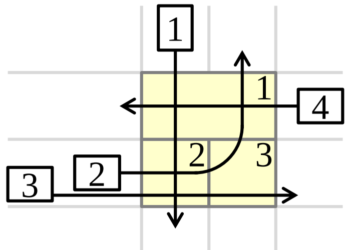
   Answer:

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	$\max_{1\le j\le 5}(s_{j+1} - s_j)$	5	$\min_{1\le i\le 4}(a_i - a_i)$	0	5
2	$\max_{1\le j\le 5}(s_{j+2} - s_j)$	8	$\min_{1\le i\le 4}(a_{i+1} - a_i)$	2	6
3	$\max_{1\le j\le 5}(s_{j+3} - s_j)$	10	$\min_{1\le i\le 4}(a_{i+2} - a_i)$	6	4
4	$\max_{1\le j\le 5}(s_{j+4} - s_j)$	11	$\min_{1\le i\le 4}(a_{i+3} - a_i)$	8	3

5. (4pts) Explain the scenario that the worst-case happens (which frame misses which time slot, and which frame suffers the worst case).

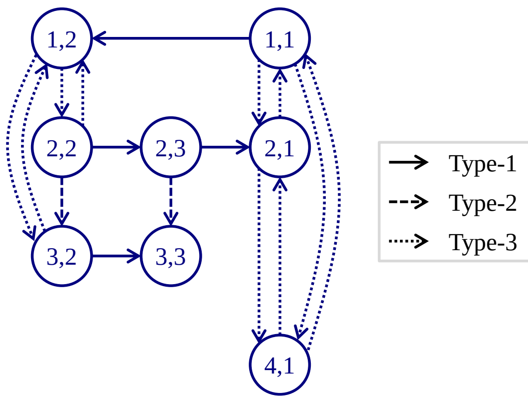
   Answer: The first frame (whose arrival time is "0") misses the third time slot (whose starting time is "3"), and the second frame (whose arrival time is "2") suffers the worst case. When the first frame's arrival time is aligned with the third time slot's starting time (shifting "3" to "0"), the second frame arrives at "2" and is served at "8" (shifting "11" to "8"), so the waiting time is 6.

3 Intersection Management (12pts)



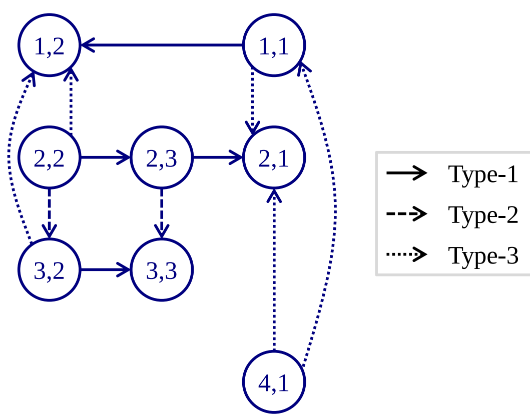
1. (6pts) Given the scenario in the figure above, draw the corresponding timing conflict graph (please follow the legend to draw different types of edges). No explanation is required.

   Answer:



2. (6pts) Following 1., given that vehicle 4 enters conflict zone 1 before vehicles 1 and 2, find a DEADLOCK solution and draw the corresponding timing conflict graph (please follow the legend to draw different types of edges). No explanation is required.

   Answer:



4 True-or-False and Multiple Choice (18pts)

Determine whether the following statements are true or false by circling the correct choice. No explanation is required. No partial credit will be given.

T F 1. (1pt) A current vehicle is more like a distributed system (there are many electronic control units, and each of them executes few tasks) rather than a centralized system (there are few electronic control units, and each of them executes many tasks).

T F 2. (1pt) The following scenario achieves level-4 autonomy: a driver can safely turn the attention away from the driving tasks, but the driver must be prepared to intervene, when called upon by the vehicle.

T F 3. (1pt) A simulated annealing approach can guarantee to find an optimal solution.

T F 4. (1pt) A traction control system is designed to prevent the wheels from loss of traction when turning.

T F 5. (1pt) For safety applications, Dedicated Short Range Communications (DSRC) needs routing, and it is supported by the Internet Protocol (IP).

T F 6. (1pt) Without human intervention, close-loop control can provide better quality of control than open-loop control in most cases.

Select ONE answer of each question. No explanation is required. No partial credit will be given.

________ 7. (2pts) Which one (or all answers) is (are) correct to describe a PID controller? (1) the proportional term is for the current error, (2) the integral term is for the future error, (3) the derivative term is for the past error, (4) all above are correct.

________ 8. (2pts) Which one has the best robustness against snow, fog, or rain? (1) automotive-use radar, (2) automotive-use lidar, (3) automotive-use camera.

________ 9. (2pts) Which one has the longest sensing range? (1) automotive-use ultrasonic sensor, (2) automotive-use radar, (3) automotive-use camera.

________ 10. (2pts) Which one is NOT a reason that the Controller Area Network (CAN) is still a better choice for in-vehicle networking than Ethernet? (1) cheap, (2) deterministic, (3) fast, (4) used for long time.

________ 11. (2pts) Which one (or all answers) is (are) the benefit(s) of cooperative adaptive cruise control? (1) congestion prevention, (2) fuel efficiency, (3) road capacity, (4) all above are correct.

________ 12. (2pts) Which one is the best to perform behavioral planning under uncertainty? (1) Markov chain, (2) hidden Markov model, (3) Markov decision process, (4) partially observable Markov decision process.

Answer: T, F, F, F, F, T, 1, 1, 3, 3, 4, 4.

5 Model Checking and Contract-Based Design (12pts)

Algorithm 1: Pseudocode

```
Input: x
y ← 20;
if x > 0 then
    for i ← 0 to x do
        if y is even then
            y ← y/2;
        else
            y ← y + 1;
        end
    end
end
```

Given the pseudocode above where x and y are integers, determine whether the following properties are true or false by circling the correct choice. $\vee$ means "OR" in Boolean algebra. No explanation is required. No partial credit will be given.

T F 1. (2pts) $\mathbf{AF}(y = 1)$.

T F 2. (2pts) $\mathbf{AG}(y \leq 20)$.

T F 3. (2pts) $\mathbf{EGF}(y = 1)$.

T F 4. (2pts) $\mathbf{EFAG}((y = 1) \vee \mathbf{X}(y = 1))$.

Answer: F, T, T, T.

5. (4pts) There are two components C_1 and C_2. C_1 satisfies a contract (A_1, G_1), and C_2 satisfies a contract (A_2, G_2). Given $A_1 \subset A_2$ and $G_1 = G_2$, which component is better, *i.e.*, which one do you want to buy if their prices are the same? Explain the reason.

Answer: C_2. If $A_1 \subset A_2$, it means that C_1 works in a "more constrained" environment, *e.g.*, C_2 which works between $[0, 100]$ degrees Celsius is better than C_1 which works between $[20, 80]$ degrees Celsius.

6 Short Answer (26pts)

1. (4pts) The optimal scheduling for an asynchronous message on a TDMA network is to schedule its time slots "as evenly as possible". Why is this not doable when you consider multiple asynchronous messages? Explain the reason.

   Answer: If the periods of two messages are co-prime, they will intend to use a same time slot, but only one message can use it.

2. (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 more conflict zones to model an intersection.

   Answer: Better expressiveness (resulting in better solution quality) but higher computational overhead.

3. (6pts) Regarding the key management for security, list one disadvantage for each of the following three approaches: pair-wise key distribution, one-key-for-all distribution, and time-delayed release of keys (timed efficient stream loss-tolerant authentication).

   Answer: Have more message authentication codes to be transmitted, have potential attacks between receivers, and have authentication delays.

4. (6pts) Assume that you are using simulate annealing to assign priorities for a set of N messages, where their transmission times are $C_0, C_1, \ldots, C_{N-1}$ and their periods are $T_0, T_1, \ldots, T_{N-1}$. The objective is to minimize the total worst-case response time of all messages, and the constraint is that the worst-case response time of each message must be smaller than its period. How will you deal with a constraint violation in simulate annealing? Explain the reason.

   Answer: Add $\sum_{i=0}^{N-1} T_i$ to the objective of each constraint violation as a feasible objective must be smaller than $\sum_{i=0}^{N-1} T_i$.

5. (6pts) In the Mixed Integer Linear Programming (MILP) formulation of the mapping problem of system design, $a_{i,k}$ is a binary variable representing that task i is allocated onto ECU k, and $t_{i,j,k,l}$ is a binary variable representing that the signal from task i to task j is packed into ECU k's message l. Why do we have the constraint:

$$\sum_{l} t_{i,j,k,l} = a_{i,k}(1 - a_{j,k})?$$

   Answer: The constraint means that, if task i is allocated onto ECU k and task j is not allocated onto ECU k (RHS=1), then the signal from task i to task j must be packed into one of ECU k's message. Otherwise, the signal does not need to be packed into one of ECU k's message (RHS=0) — if tasks i and j are both allocated onto ECU k, the signal does not need to be transmitted; if task i is not allocated onto ECU k, the signal is not transmitted from ECU k.

7 MILP Formulation (8pts)

1. (2pts) There are two vehicles toward the same direction along a straight lane. Their lengths are both L, and the coordinates of their centers are (x_a, Y) and (x_b, Y), where Y is a constant. Write the mathematical constraint that the gap between the two vehicles is larger than a constant C. The constraint does not need to be in an MILP form.

   Answer: $|x_a - x_b| > (C + L)$.

2. (6pts) Transform the constraint into an MILP form and prove the equivalence. Warning: this may be the most difficult question in the midterm.

   Answer: Add a binary variable x and a sufficiently-large constant M (*e.g.*, the length of the lane or the perimeter of the earth) and transform the constraint into

   $$x_a - x_b < z(C + L + M) - (C + L) \text{ and } x_a - x_b > z(C + L + M) - (M).$$

   When $x_a - x_b > (C + L)$, z can be set as 1, and the constraints

   $$x_a - x_b < (M) \text{ and } x_a - x_b > (C + L)$$

   are satisfied. When $x_a - x_b < -(C + L)$, z can be set as 0, and the constraints

   $$x_a - x_b < -(C + L) \text{ and } x_a - x_b > -(M)$$

   are satisfied. When $|x_a - x_b| \leq (C + L)$, no matter how to set z, the constraints are not satisfied.