RTES Exercise 2

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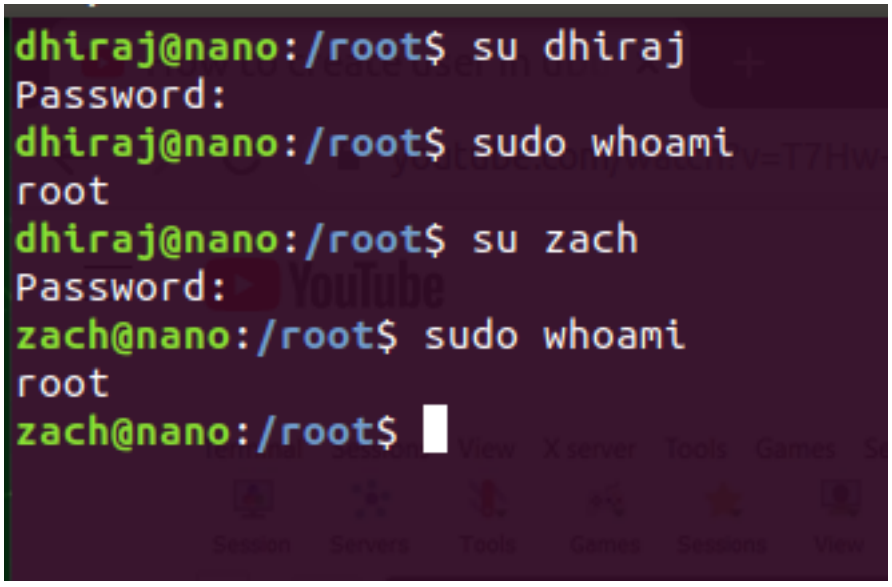
Question 1



An account has been created in the names of both the user Dhiraj and Zach and root privileges are given to both the users

Question 2

Frequency Executive Advantages

1. Can maintain 40 millisecond periods through the cyclic executive for the high frequency tasks with higher priority
2. Can reliably handle a variety of frequency services by setting appropriate priorities and allowing the scheduler to preempt low-frequency tasks with high-frequency ones.

3. Frequency executive scheduling can provide more deterministic run time which is easier to test and validate with extremely low or no MTBF (mean time between failures). Real-time scheduling is much harder to have the same test coverage and confidence.

Frequency Executive Disadvantages

1. Requires well understood, deterministic service release times and core affinity to be able to schedule tasks with varying priorities based on frequency.
2. Not a flexible solution if last minute principal functions need to be added or adjusted
3. Real-time threading can better handle asynchronous tasks. Frequency executives require either a central timekeeper or a polling of asynchronous tasks.

Question 3

Cyclic Executive Architecture has the following properties

1. The Architecture has predictable outputs and can easily be tested as there is no interleaving of operations
2. Code can have smaller footprint
3. Code is difficult to maintain through developmental stages
4. The architecture will have low abstraction level

   The above mentioned points can be overcome by using reusable software components such as abstract data types and generic packages or templates

Key points in the Paper

(a) Cyclic Schedule is a table which contains a full execution pattern for a major cycle.

(b) A dynamic recovery policy will be adopted for failure recovery.

(c) Cyclic Scheduler is iterative procedure that allows the explicit multiplexing of periodic processes set in one processor.

The following parameters should be configurable in the cyclic architecture

i. Duration of minor and major cycle periods

ii. Number of minor cycles per major cycle

iii. Maximum number of frames per minor cycle
iv. Process (reference to procedure) that has to be executed in each frame

Differences in Cyclic Executive and Linux Posix threads

Cyclic Executive	**Linux RT Threads**
Low Abstraction Level	High Abstraction Level
Difficult to maintain as changes/addition creates ripple throughout	Addition of functionality is easier
No concept of priority	Priority levels exits
Pre-Analysis for developing Architecture is huge	Can dynamically adapt new features with less complexity
Predictable Response	Mostly predictable
Low footprint and overhead	Footprint is large
No context switch except for interrupts	Context switch for switching between different priority threads

Question 4

Summary of Results

Test	Rate Monotonic		Dynamic Priority
	Completion Test Feasibility	Scheduling Point Feasibility	EDF Feasibility
0			
1			
2			
3			
4			
5			
6			
6 - DM			
7			
8			
9			

Code Output

```
zturner@jetson-nano:~/projects/rtes/e2$ ./feasibility_tests
Ex-0 U=0.733333 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=10, D1=10};   {S2: C2=2, T2=15, D2=15})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-1 U=0.985714 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=2, T2=7, D2=7})
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-2 U=0.996703 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=13})
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-3 U=0.933333 ({S0: C0=1, T0=3, D0=3};   {S1: C1=2, T1=5, D1=5};   {S2: C2=3, T2=15, D2=15})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-4 U=1.000000 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=4, D1=4};   {S2: C2=4, T2=16, D2=16})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-5 U=1.000000 ({S0: C0=1, T0=2, D0=2};   {S1: C1=2, T1=5, D1=5};   {S2: C2=1, T2=10, D2=10})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-6 U=0.996703 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=13})
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-7 U=1.000000 ({S0: C0=1, T0=3, D0=3};   {S1: C1=2, T1=5, D1=5};   {S2: C2=4, T2=15, D2=15})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-8 U=0.996703 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=13})
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-9 U=1.000000 ({S0: C0=1, T0=6, D0=6};   {S1: C1=2, T1=8, D1=8};   {S2: C2=4, T2=12, D2=12};   {S3: C3=6, T3=24, D3=24})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-6_DM U=0.992857 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=4};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=20})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: INFEASIBLE
Dynamic Priority Feasibility: INFEASIBLE
```

```
Ex-0 U=0.733333 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=10, D1=10};   {S2: C2=2, T2=15, D2=15})
RM LUB = 0.779763
RM LUB Test Feasibility: FEASIBLE
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-1 U=0.985714 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=2, T2=7, D2=7})
RM LUB = 0.779763
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-2 U=0.996703 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=13})
RM LUB = 0.756828
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-3 U=0.933333 ({S0: C0=1, T0=3, D0=3};   {S1: C1=2, T1=5, D1=5};   {S2: C2=3, T2=15, D2=15})
RM LUB = 0.779763
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-4 U=1.000000 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=4, D1=4};   {S2: C2=4, T2=16, D2=16})
RM LUB = 0.779763
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-5 U=1.000000 ({S0: C0=1, T0=2, D0=2};   {S1: C1=2, T1=5, D1=5};   {S2: C2=1, T2=10, D2=10})
RM LUB = 0.779763
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE
```

```
Ex-6 U=0.996703 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=13})
RM LUB = 0.756828
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-7 U=1.000000 ({S0: C0=1, T0=3, D0=3};   {S1: C1=2, T1=5, D1=5};   {S2: C2=4, T2=15, D2=15})
RM LUB = 0.779763
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-8 U=0.996703 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=5};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=13})
RM LUB = 0.756828
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: INFEASIBLE
Scheduling Point Feasibility: INFEASIBLE
EDF Feasibility: FEASIBLE

Ex-9 U=1.000000 ({S0: C0=1, T0=6, D0=6};   {S1: C1=2, T1=8, D1=8};   {S2: C2=4, T2=12, D2=12};   {S3: C3=6, T3=24, D3=24})
RM LUB = 0.756828
RM LUB Test Feasibility: INFEASIBLE
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: FEASIBLE
EDF Feasibility: FEASIBLE

Ex-6 DM U=0.992857 ({S0: C0=1, T0=2, D0=2};   {S1: C1=1, T1=5, D1=4};   {S2: C2=1, T2=7, D2=7};   {S3: C3=2, T3=13, D3=20})
Completion Test Feasibility: FEASIBLE
Scheduling Point Feasibility: INFEASIBLE
Dynamic Priority Feasibility: INFEASIBLE
```

Earliest Deadline First Feasibility Test

The feasibility test that was used for Earliest Deadline First scheduling was taken from the paper Preemptive and Non-Preemptive Real-Time UniProcessor Scheduling [1].

The images for each of the tests are arranged in the pdf file available at below location

Question 4 Results

Question 5

Assumptions made in the Paper

(a) All services are requested on periodic basis, the period is constant

(b) The completion time of a service is less than its period

(c) Service Requests are independent (No Known Phasing)

(d) Runtime is known and deterministic

(e) Critical Instant - Longest service time for a response occurs when all the system services are requested simultaneously (maximum interference case for lowest priority service)

Constraints

(a) Deadline of a service is equal to the period

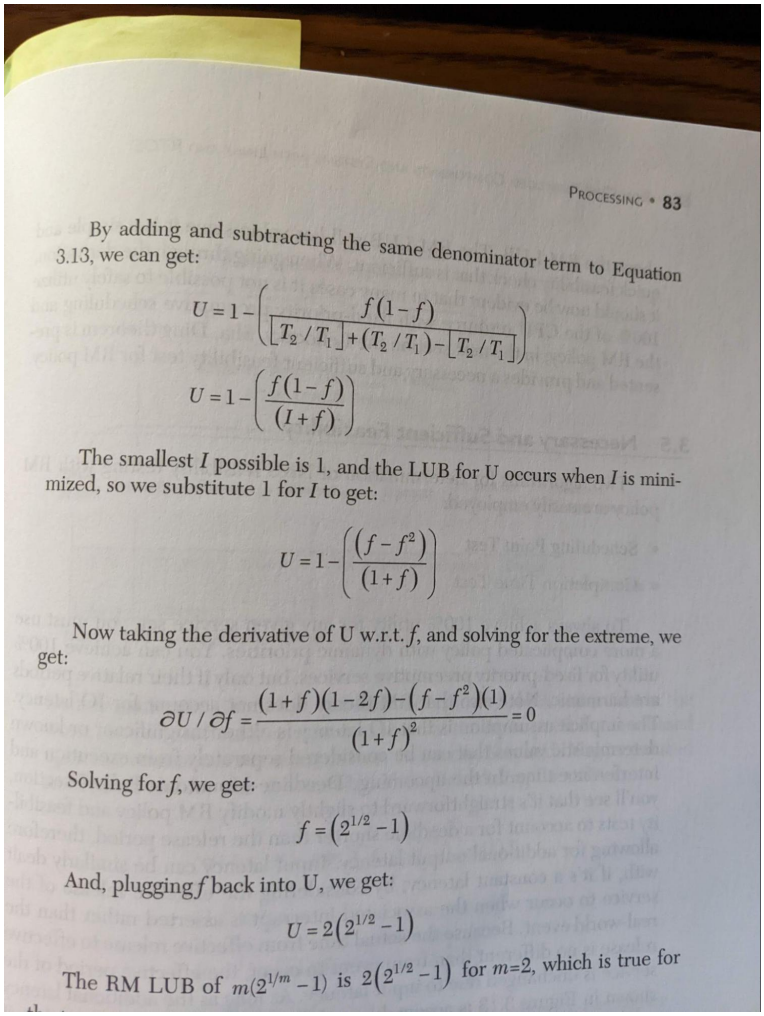
(b) Fixed Priority, Preemptive, Run to Completion Scheduling

(c) Does not include Secondary, Tertiary Resource Issue

(d) Fails in cases where Dynamic Priorities succeed

The RM LUB is a pessimistic feasibility test that will fail some proposed service sets that actually work, but it will never pass a set that doesn't work. RM LUB is a sufficient feasibility test but not necessary.

Parts of the paper that contains complicated Math



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By adding and subtracting the same denominator term to Equation 3.13, we can get:

$$U = 1 - \left(\frac{f(1-f)}{\lceil T_2 / T_1 \rceil + (T_2 / T_1) - \lceil T_2 / T_1 \rceil} \right)$$

$$U = 1 - \left(\frac{f(1-f)}{(I+f)} \right)$$

The smallest I possible is 1, and the LUB for U occurs when I is minimized, so we substitute 1 for I to get:

$$U = 1 - \left(\frac{(f - f^2)}{(1+f)} \right)$$

Now taking the derivative of U w.r.t. f, and solving for the extreme, we get:

$$\partial U / \partial f = \frac{(1+f)(1-2f) - (f - f^2)(1)}{(1+f)^2} = 0$$

Solving for f, we get:

$$f = \left(2^{1/2} - 1\right)$$

And, plugging f back into U, we get:

$$U = 2\left(2^{1/2} - 1\right)$$

The RM LUB of $m(2^{1/m} - 1)$ is $2\left(2^{1/2} - 1\right)$ for m=2, which is true for

Moving from 3.12 to 3.13

Rationale: We never would have thought to separate integer interference from fractional interference, but it creates a convenient utility function

$$U = \frac{T_2 - T_1\lfloor T_2/T_1 \rfloor}{T_1} + \frac{T_2 - C_1\lceil T_2/T_1 \rceil}{T_2}$$

$$U = \frac{T_2 - T_1\lfloor T_2/T_1 \rfloor}{T_1} + \frac{T_2 - (T_2 - T_1\lfloor T_2/T_1 \rfloor)\lceil T_2/T_1 \rceil}{T_2}$$

$$U = \frac{T_2 - T_1\lfloor T_2/T_1 \rfloor}{T_1} + \frac{T_2 - T_2\lceil T_2/T_1 \rceil + T_1\lfloor T_2/T_1 \rfloor\lceil T_2/T_1 \rceil}{T_2}$$

$$U = (T_2/T_1) - \lfloor T_2/T_1 \rfloor + 1 - \lceil T_2/T_1 \rceil + (T_1/T_2)\lfloor T_2/T_1 \rfloor\lceil T_2/T_1 \rceil$$

$$U = 1 - \lceil T_2/T_1 \rceil + (T_1/T_2)\lfloor T_2/T_1 \rfloor\lceil T_2/T_1 \rceil + (T_2/T_1) - \lfloor T_2/T_1 \rfloor$$

$$U = 1 - (T_1/T_2)\left((T_2/T_1)\lceil T_2/T_1 \rceil - \lfloor T_2/T_1 \rfloor\lceil T_2/T_1 \rceil - (T_2/T_1)^2 + (T_2/T_1)\lfloor T_2/T_1 \rfloor\right)$$

$$U = 1 - (T_1/T_2)\left[\lceil T_2/T_1 \rceil - (T_2/T_1)\right]\left[(T_2/T_1) - \lfloor T_2/T_1 \rfloor\right] \quad (3.12)$$

Now, let whole integer number of interferences of S_1 to S_2 over T_2 be $I = \lfloor T_2/T_1 \rfloor$ and the fractional interference be $f = (T_2/T_1) - \lfloor T_2/T_1 \rfloor$. From this, we can derive a simple expression for utility:

$$U = 1 - \left(\frac{f(1-f)}{(T_2/T_1)}\right) \quad (3.13)$$

The derivation for Equation 3.11 is based upon substitution of I and f into Equation 3.12 as follows:

$$U = 1 - (T_1/T_2)\left[\lceil T_2/T_1 \rceil - (T_2/T_1)\right]\left[(T_2/T_1) - \lfloor T_2/T_1 \rfloor\right]$$

$$U = 1 - (T_1/T_2)\left[1 + \lfloor T_2/T_1 \rfloor - (T_2/T_1)\right]\left[(T_2/T_1) - \lfloor T_2/T_1 \rfloor\right]$$ based on ceiling(N.d) = 1 + floor(N.d)

$$U = 1 - (T_1/T_2)\left[1 - \left((T_2/T_1) - \lfloor T_2/T_1 \rfloor\right)\right]\left[(T_2/T_1) - \lfloor T_2/T_1 \rfloor\right]$$

$$U = 1 - (T_1/T_2)(1-f)(f)$$

$$U = 1 - \left(\frac{f(1-f)}{(T_2/T_1)}\right)$$

Adding and subtracting same value to denominator
Rationale: It's interesting to add more expressions into the derivation so that we can represent the integer interference

Taking the derivative of U w.r.t f and solving for the extreme
Rationale: Taking the derivative of U w.r.t f and solving for the extreme

References

[1] Laurent George, Nicolas Rivierre, Marco Spuri. Preemptive and Non-Preemptive Real-Time UniProcessor Scheduling. [Research Report] RR-2966, INRIA. 1996. ffinria-00073732

[2] Code Source: http://mercury.pr.erau.edu/ siewerts/cec450/code/
Courtesy: Dr Sam Siewert
Professor Tim Scherr