

# Indian Institute of Technology Guwahati

## Department of Computer Science and Engineering

End Semester Examination

Course: CS528 (High Performance Computing)

Date: 6<sup>th</sup> May 2022

Timing: 2.00PM-5.00PM

(Write assumption clearly if you assume anything for answering question)

Full Marks: 60

### 1. [8 (=3+5) Marks] [Basic Scheduling]

- Describe the problem  $P | p_j, no-pmtn, d_j=D, a_j=0 | \sum U_j$
- Solve the above mentioned problem efficiently. Assume  $p_i \leq D$ .

### 2. [12 (=6+6) Marks] [Reliability and Robustness]

- Given an application represented using directed tree with  $N$  nodes, each node execution time is one unit. There are  $k$  nodes in its critical path. All the partial critical paths need to be executed in homogeneous processor/VMs with unit processing speed. To ensure robustness up to three nodes failure and to achieve the minimum  $C_{max}$ , calculate the number of VMs required.
- Given an application with  $N$  independent non-pre-emptive tasks and  $m$  homogeneous processor but with different failure rates  $f_1 \leq f_2 \leq \dots \leq f_m$ . The reliability of task execution is calculated as  $\exp(-f \cdot t)$ , where  $f$  is the failure rate of the machine and  $t$  is the execution time of the task. System reliability ( $R_{sys}$ ) is product of reliability of all the tasks. Design an approach to schedule the task in a such a way that it primarily minimizes  $C_{max}$  and secondarily maximize the system reliability  $R_{sys}$ .

### 3. [10 (6+4) Marks] [Resource Prediction in Cloud System]

- Suppose you are using an EWMA predictor  $E(t) = \alpha * E(t-1) + (1-\alpha) * O(t)$  with  $\alpha = 0.5$ , where  $E(t)$  and  $O(t)$  are estimated and observed values at time  $t$ . There is another person, who knows that you use the EWMA model and he/she wants you to make the maximum prediction error and he/she is the person who decides the observed values (between 0 to 100). Assume the initial estimated value is 0. In a long run, what will be the prediction error in percentage?
- Suppose, you figure out that he/she is fooling you, how can you change your strategy to minimize the error? You may switch to another predictor (or change the  $\alpha$  value) but the other person still assumes that you are using EWMA prediction with the same  $\alpha$  value and he/she continue to pass the observed value based on that.

### 4. [12 (=6+6) Marks] [Resource Consolidation and DVFS]

- Given a cloud data centre with  $m_1$  type1 machine,  $m_2$  type2 machines, and total  $M (=m_1+m_2)$  machines. Power consumption model of type1 and type2 machines are given as  $P_{type1} = 200 + 20 * u^3$  and  $P_{type2} = 50 + 100 * u^3$ , where  $u$  is normalized processor utilization of the machine ( $0 < u \leq 1$ ). There are  $N$  webserver tasks (which runs forever) and each task have expected machine utilization  $u_i$  (for  $i$ th task). Design an approach to map these webserver tasks onto these machines such that total power consumption of the data centre is minimized.
- Design an optimal approach to solve  $P | p_j, no-pmtn, d_j, a_j=0 | \sum E_j$ , where the power consumption of the processor is modelled as  $P = \alpha * f^3$  and number of processor  $m = \infty$ ,  $E_j$  is the energy consumption of the task on the processor. Assume  $p_i \leq d_i$ ,  $0 < f \leq 1$  and execution time of task on a processor running at frequency  $f$  is  $p_i/f$ .

### 5. [10(=4+6) Marks] Roop-line Model and Serial Code Opt.

- Given a computer system with peak performance of 12TF/s and achievable data bandwidth to the compute is 100GB/s. Calculate the expected performance of the following code on the system assuming the size of a float data is 4B and system uses write allocate mode.  

```
for(i=0; i<N; i++) { a[i]=s*b[i]+c[i]*d[i]; } //float a[N], b[N], c[N], d[N];
```
- Suppose we want to implement an average filter of  $w \times w$  size over an Image of size  $N \times N$  pixels. Assume  $w$  is odd value and for every pixel position we need to put average of total  $w^2-1$  surrounded pixels and own pixel value. Design an efficient approach to calculate the filtered Image. Analyse the time complexity of your approach in terms of  $N$  and  $w$ . You may assume you can use a data type (similar to `int` in Python) which can store unlimited precision data.

### 6. [8 (=4+4) Marks] MPI, Amdhal's Law and Computer Network

- Suppose a page ranking software is written in MPI and which has a lot of Map-Reduce constructs and is dominated by many reduce (MPI\_reduce) operations. Suggest a target interconnection network architecture of the data center to efficiently run the application with minimum interconnection cost.
- Write four possible reasons that may be responsible for achieving superlinear speed up ( $T_1/T_p = S_p > p$ ), where  $p$  is the number of processors.