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M.Sc. in Cloud Computing – Full-time – Year 1 - MSCLOUDNCI1
M.Sc. in Cloud Computing – Full-time – Year 1 - MSCCLOUD_JAN19O
Post Graduate Diploma in Cloud Computing – Part-time – Year 1 - PGDCLOUD

Semester One Examinations – 2019/2020

Thursday 9th January 2020
6.30pm – 8.30pm

Cloud Architecture

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Answer all Questions

Duration of exam: 2 hours
Attachments: None.

Requires: Calculator

1) AMD launched its 12-core Ryzen 9 3900X processor with dual clock 3.8 and 4.6 GHZ during the first half of 2019. For the purpose of this exercise, consider only 6 of those cores—labelled "A" to "F"—and assume they have variable processing capabilities. Assume these six cores are calculating a double precision vector-matrix multiplication using the operations `saxpy`[1] for vectors X and Y of length 512. Assume cores A and F have the same processing capabilities, B and C run twice as fast as A, and D and E 4 times faster. Assume 1 time unit per `daxpy` on A or F for a vector pair (x[i] and y[i]). Given the following division of labour on the six cores:

- A= 128 vector pairs;
- B= 64 vector pairs;
- C= 64 vector pairs;
- D= 128 vector pairs;
- E=64 vector pairs; and,
- F= 64 vector pairs.

a) Compute completion time **(5 marks)**

b) Calculate core utilisation rate **(10 marks)**

c) Propose an improved allocation of tasks to processors and calculate its utilisation rate (5 marks).

[Total: 20 Marks]

2) Describe a Hadoop architecture, delineating the roles of the key components and the HA, scalability and fault resilience/tolerance features it provides.

[TOTAL: 20 marks].

[1] saxpy stands **S**ingle-precision **aX** **P**lus **Y**. A saxpy operation performs `y[i] = a * x[i] + y[i];` for `i=1` to `n`.

3) Assume a cluster with redundancy in a given datacentre. When a node fails, it takes 10 seconds to diagnose the fault and another 30 seconds for the workload to switch over.

   a) What is the availability of the cluster if planned downtime (maintenance) is ignored?. **(5 marks)**
   b) What is the availability of the cluster including planned downtime?. Assume the cluster is off one hour per week for maintenance. **(10 marks)**
   c) The datacentre SLA states four nines. What is the maximum planned downtime per week to fulfil with the SLA, assuming one failure per year? **(10 marks)**.
   d) Discuss an architectural approach to improving general system availability using an example **(5 marks)**.

[Total 30 Marks]

4) Consider the standard matrix multiplication method for two square matrices as shown below:

$$\begin{pmatrix} a11 & a12 & a13 \\ a21 & a22 & a23 \\ a31 & a32 & a33 \end{pmatrix} \begin{pmatrix} b11 & b12 & b13 \\ b21 & b22 & b23 \\ b31 & b32 & b33 \end{pmatrix} =$$

$$\begin{pmatrix} a11.b11 + a12.b21 + a13.b31 & a11.b12 + a12.b22 + a13.b32 & a11.b13 + a12.b23 + a13.b33 \\ a21.b11 + a22.b21 + a23.b31 & a21.b12 + a22.b22 + a23.b32 & a21.b13 + a22.b23 + a23.b33 \\ a31.b11 + a32.b21 + a33.b31 & a31.b12 + a32.b22 + a33.b32 & a31.b13 + a32.b23 + a33.b33 \end{pmatrix}$$

Figure 1. 3x3 Matrix multiplication (credits: NCalculators.com)

Given matrices of order M (MxM), the time complexity of the sequential multiplication time can be defined as $T_1 = cM^3$ units of time, where c is a hardware-dependant constant.
Assume that a MPI parallel code requires $Tn = cM^3/n + dM^2/n$ units of time to complete on a n-node configuration, where d is a constant determined by the MPI implementation used. The second term in Tn accounts for the total message passing overhead experienced.

Answer the following questions assuming the MPI parallel code has no sequential bottleneck, is used for a matrix of order 256 ($M=256$), and executed on a 4096-node cluster ($n=4096$) with a hardware configuration with constant $c=1$. For parts a) and b) assume an implementation of MPI (e.g MPICH-2) with $d=4$.

[30 marks]

a) Using the canonical Amdahl's law, calculate the speedup of the parallel code on n nodes.

[10 marks]

b) What is the efficiency of the n-node cluster

[10 marks]

c) Assume now a MPI implementation which incorporates the MPI-3 RMA interface and has a $d=0$.

i. What is the new speedup and efficiency on n nodes?

[5 marks]

ii. Please explain the RMA concept and its relation to the d parameter, ideally using the following module reference papers:

- M Snir: Technical perspective: The future of MPI. *CACM* 61(10): 105 (2018)
- R Gerstenberger, M Besta, T Hoefler: Enabling highly scalable remote memory access programming with MPI-3 one sided. *CACM* 61(10): 106-113 (2018).

[5 marks]