THE UNIVERSITY OF WARWICK
Fourth Year Examinations: Summer 2015
High Performance Computing

Time allowed: 3 hours
Answer FOUR questions.
Calculators may be used.
Read carefully the instructions on the answer book and make sure that the particulars required are entered on each answer book.

1. (a) Discuss the differences between vector processors and MPP (Massively Parallel Processing) machines. [6]

(b) Explain three general approaches to achieving high performance from the perspective of hardware and give an example for each approach. [6]

(c) What do we mean by the Granularity of Parallelism? Give four types of parallelism in order of granularity and provide an application example for each. [9]

(d) Analyse the two "for" loops in Listing 1. Describe whether the iterations of these two loops can be parallelised automatically by compilers and explain how you reached your conclusions. [4]

Continued

2 (a) The data to be sent in the MPI_Send routine is represented by a triple, (*address*, *count*, *datatype*), where *address* is the starting address of the data, *count* is the number of data items and *datatype* is the type of the data. Discuss the advantages of this representation over using the alternative pair (*address*, *length*) to represent the data to be sent. In (*address*, *length*), *address* is the starting address of the data and *length* is the number of bytes that the data occupies. [6]

(b) The Ready Mode is an MPI communication mode. Explain the circumstance under which Ready Mode communication can be used and discuss the benefits of using Ready Mode communication. [5]

(c) A collective communication operation is performed by all relevant processes at the same time with the same set of parameters. However different processes may interpret the parameters differently. Describe, using illustrative examples if necessary, the operations of the following two MPI collective communication calls. Further, discuss how different processes interpret different parameters in MPI_Scatter.

i) MPI_Barrier(MPI_Comm *Comm*)

ii) MPI_Scatter(void **sendbuf*, int *sendcnt*, MPI_Datatype *sendtype*,
void **recvbuf*, int *recvcount*, MPI_Datatype *recvtype*, int *root*,
MPI_Comm *comm*) [8]

(d) *MPI_Type_struct* can be used to construct the users' own data types. The format of the function is as follows:

MPI_Type_*struct* (int *count*,
int **array_of_blocklengths*,
MPI_Int **array_of_displacements*,
MPI_Datatype **array_of_types*,
MPI_Datatype **newtype*)

Let *oldtype1* ={(MPI_CHAR, 0), (MPI_INT, 8)} with the extent of 24 bits (3 bytes) and oldtype2={(MPI_FLOAT, 0), (MPI_INT, 32)} with the extent of 48 bits (6 bytes). Let B=(1, 2), D=(2, 20) and C=(*oldtype1*, *oldtype2*). Note that the parameter **array_of_displacements* holds the BYTE displacement of each block.

Give the memory layout of *newtype* after calling
MPI_Type_*struct* (2, B, D, *C*, *newtype*). [6]

Continued

3. (a) Describe what dependencies exist in the following sequence of statements. Explain how to remove the anti-dependency and the output dependency in these statements.

```
if(a==0){
    a=b;
    b=2× c;
}
else {
    b=a×b;
    d=b+e;
    a=a+c;
    d=c×a;
 }
```

[12]

(b) Explain the differences between the "Private" variable and the "Reduction" variable in OpenMP. [5]

(c) Give three ways of setting the number of threads generated in a parallel region in OpenMP. [3]

(d) Discuss why OpenMP is a higher level parallelism than MPI. [5]

4. (a) Discuss the drawbacks of using asymptotic analysis to evaluate the performance of an algorithm. [5]

(b) Amdahl's law states that if the fraction of the part that has to be run in sequence in a program is f, then the maximum speed that the program can achieve is $1/f$. Derive the process of obtaining the maximum speed of $1/f$. [5]

(c) Explain what the iso-efficiency function is. Assume a program has the following expression for calculating its parallel efficiency, E, where N is the problem size and P is the number of processors. Derive the iso-efficiency function of the program and explain your answer.

$$E = \frac{2N^2}{3N^2 + P^2 + 5NP}$$

[5]

(d) Modelling the execution time of an application is a good way of evaluating the performance of the application. Discuss how to model the execution time of an application. The discussion should explain the equations used to calculate computation time and communication time. Also, the discussion should describe various parameters that should be considered when modelling the execution time. [10]

Continued

5. (a) What aspects of network performance do *node degree*, *bisection width* and *diameter* in a network represent, respectively? Figure 1 shows the interconnection topologies of a 2D mesh and a 2D torus, where "S" represents a switch and "P" represents a processor, and an edge between two switches represents a communication link. What are the node degree, bisection width and diameter of these two topologies? [9]

   (b) Describe the general principles of combining MPI and OpenMP to write parallel programs. [6]

   (d) What does single system image mean in Cluster systems? Discuss the benefits of providing a single system image in Cluster systems. [10]

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6. (a) Using data replication and parity information are two possible solutions to handling disk failures. Discuss the advantages and disadvantages of these two solutions? [6]

   (b) Explain the similarities between RAID5 and RAID3, and discuss the advantages of RAID5 over RAID3. [3]

   (c) When one or more processes update the same data, I/O consistency needs to be maintained. Explain why the I/O accesses may not be consistent. Describe three methods that can be used to ensure I/O consistency. [6]

   (d) There are three potential methods to implement parallel I/O: 1) One process performs I/O operations for all other processes; 2) Each process reads or writes the data from or to a separate file; 3) Different processes access different parts of a common file. Discuss the advantages and disadvantages of each method. Which method of parallel I/O is most widely used nowadays? [10]

End

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Supplementary Information.
Listings and Figures to accompany the CS4022 question paper

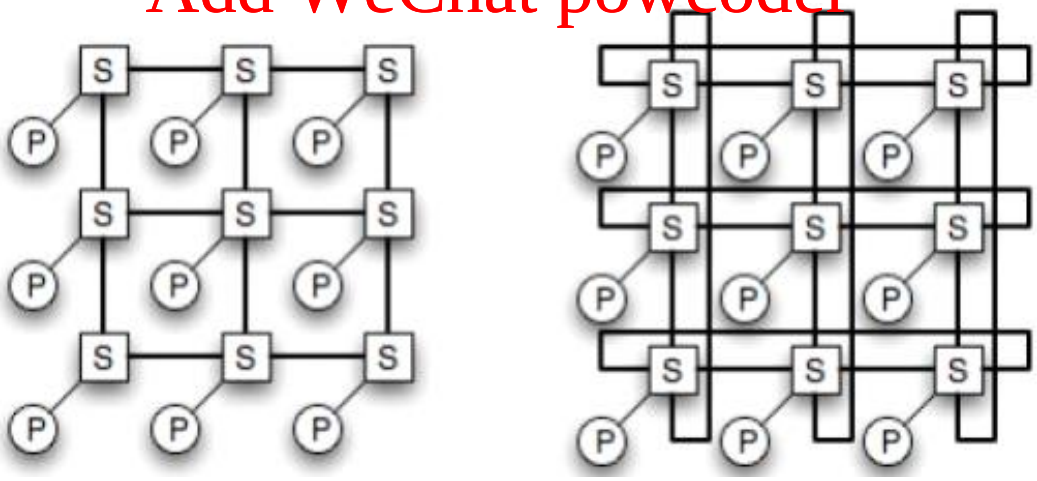
Segment 1:

```
for(i=1; i<=N; i++)
{
    A(i)= B(i-1) ×B(i-2);
    B(i)= A(i) ×B(i);
}
```

Segment 2:

```
for(i=3; i<=N; i++)
{
    A(i)= A(i-1) × B(i);
    B(i)= B(i-2) × B(i-1);
}
```


Listing 1: Code segments for Question 1(d)



(a) 2D mesh (b) 2D torus

Figure 1. Network Topologies for Question 5(a)

End