



THE UNIVERSITY OF WESTERN AUSTRALIA

1ST SEMESTER EXAMINATIONS 2002

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

ADVANCED COMPUTER ARCHITECTURE 319 (623.319)

This Paper Contains:

7 Pages

10 Questions

Time Allowed: 3 Hours

Reading Time: 10 Minutes

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SEE OVER

QUESTION 1 (10 Marks)

Consider the following loop:

```
Do 10 I=1,20
    S1: A(I)=X(I)-3
    S2: B(I+1)=A(I)*C(I+1)
    S3: C(I+4)=B(I)+A(I+1)
    S4: D(I+2)=D(I)+D(I+1)
    S5: C(I+3)=X(I)
10 Continue
```

Draw the dependence graph for the above program portion.

QUESTION 2 (8 Marks)

When designing or selecting a network topology, several performance parameters must be considered. List 6 such performance parameters.

QUESTION 3 (12 Marks)

Consider a vector computer that can operate in one of two execution modes at a time: one is the *vector mode* with an execution rate of $R_v=10$ Mflops, and the other is the *scalar mode* with an execution rate of $R_s=1$ Mflops. Let α be the percentage of code that is vectorizable in a typical program mix for this computer.

- Derive an expression for the *average execution rate* R_a for this computer.
- Plot R_a as a function of α (for α in the range of 0 to 1).
- Determine the vectorization ratio α needed in order to achieve an average execution rate of $R_a=7.5$ Mflops.
- Suppose $R_s=1$ Mflops and $\alpha=0.7$. What value of R_v is needed to achieve $R_a=2$ Mflops?

QUESTION 4 (10 Marks)

How long will the following computation take if executed on an architecture that does not allow pipelining and chaining, and how long on an architecture that does (like the CRAY X-MP).

```
for I = 1 to 64
    C(I) = A(I) + B(I)
    D(I) = C(I) * E(I)
endfor
```

where the vectors A,B, and E are already loaded into vector registers, and the results C and D are to be stored back into registers (so ignore any memory transfer requirements). Assume the existence of two functional units (one for multiplication that takes 7 cycles/multiplication and the other for additions that takes 6 cycles/addition). Also assume that one clock period is required for transferring data from a register to the arithmetic unit and vice versa. Demonstrate your answer by drawing a chaining diagram, and a space-time diagram.

QUESTION 5 (14 Marks)

The following program is to be executed on a uniprocessor, and a parallel version is to be executed on a shared-memory multiprocessor.

```
S1:   for I = 1, 1024 do
S2:       SUM[I] = 0
S3:       if (I <= 512) then
S4:           for J = 1, I do
S5:               SUM[I] = SUM[I] + I
S6:           endfor J
S7:       else
S8:           for J = 1, (1025-I) do
S9:               SUM[I] = SUM[I] + I
S10:        endfor J
S11:    endif
S12: endfor I
```

Assume that the statements S2, S5 and S9 each take two machine cycle times, including all CPU and memory-access activities. Ignore the overhead caused by the software loop control (statements S1, S4, S6, S8, S10 and S12), conditional statements (S3, S7 and S11) and all other system overhead and resource conflicts.

- Plot the amount of work involved (the number of cycles required) in each iteration of the outer loop against the loop index I (for I from 1 to 1024).
- What is the total execution time (in cycles) of the program on a uniprocessor?
- Divide the outer loop iterations among 32 processors as follows: Processor 1 executes the first 32 iterations (I = 1 to 32), Processor 2 executes the next 32 iterations (I = 33 to 64), and so on. What is the execution time and the speedup compared with the uniprocessor considered in part (a)?
- Modify the given program to facilitate a balanced parallel execution of all the computational workload over 32 processors. What is the execution time resulting from the balanced program? What is the new speedup? Assume that any overhead associated with flow control is neglected.

QUESTION 6 (14 Marks)

Write a CREW PRAM algorithm that calculates the dot product of two vectors **A** and **B**, which have N elements each. The algorithm should use N processors and have $O(\log N)$ time complexity.

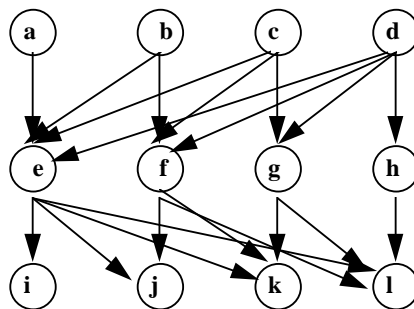
Recall that the dot product of two vectors is found from:

$$\mathbf{A} \cdot \mathbf{B} = \sum_{i=1}^N a_i \times b_i$$

where a_i and b_i are the i -th elements of the vectors **A** and **B**, respectively.

QUESTION 7 (8 Marks)

Consider the task graph shown in the figure below. The size of each task is 1 time unit and the communication delays between different tasks are equal to 1 time unit (when the tasks are assigned to different processors).



The task graph is to be mapped onto a three processor parallel processor system to minimize the schedule length. Draw the Gantt chart showing the allocation and ordering of tasks on processors (as well as their start and finish times) and compute the total time needed to execute the task graph. Note: you should be able to find the optimal schedule fairly easily in this situation.

QUESTION 8 (8 Marks)

While caches are highly desirable in multiprocessor systems, they introduce the *cache coherence* problem, which is a major obstacle in building very large shared-memory systems.

Explain what the cache coherence problem is and briefly describe two methods used to rectify it (while still having local/private caches).

QUESTION 9 (10 Marks)

Consider the following 4-stage pipeline reservation table:

	0	1	2	3	4	5	6
S1	X						X
S2		X				X	
S3			X		X		
S4				X			

- What are the forbidden latencies?
- Draw the state transition diagram.
- List all the simple cycles and greedy cycles?
- Determine the minimal average latency (MAL).
- Let the pipeline clock period be $\tau=20\text{ns}$. Determine the throughput of this pipeline.

QUESTION 10 (6 Marks)

Answer the following questions for the k -ary n -cube network:

- a) How many nodes are there?
- b) What is the network diameter?
- c) What is the bisection width?
- d) What is the node degree?
- e) What is the relationship between this topology and rings, meshes, torii, and hypercubes?