

**EE482B Advanced Computer Architecture and Organization  
Midterm Exam Spring 2003**

**May 7<sup>th</sup>, 2003  
Version  $\gamma$  0.3**

**(Total time = 75 minutes, Total Points = 100)**

**Name: (please print)** \_\_\_\_\_

**In recognition of and in the spirit of the Stanford University Honor Code, I certify that I will neither give nor receive unpermitted aid on this exam.**

**Signature:** \_\_\_\_\_

**This examination is closed notes closed book except that you may refer to at most 1 page of notes that you have prepared yourself. You may not collaborate in any manner on this exam. You have 1 hour and 15 minutes to complete the exam. Before starting, please check to make sure that you have all 7 pages.**

<b>1</b>	<b>40</b>	
<b>2</b>	<b>20</b>	
<b>3</b>	<b>20</b>	
<b>4</b>	<b>20</b>	
<b>Total</b>	<b>100</b>	

Name: \_\_\_\_\_

**1. Short Answer (40 points, 5 points each)**

- A. True or False: A well-designed minimal adaptive routing algorithm will usually outperform a well-designed non-minimal oblivious algorithm on worst-case traffic. Give a one sentence rationale for your answer.
- B. In a network using virtual-cut-through flow control, how does increasing the number of packet buffers at each node affect the zero load latency  $T_0$  (increases, stays the same, decreases)?
- C. True or False: A folded-Clos network using minimal routing (adaptive or oblivious) and wormhole flow-control is deadlock free with only a single virtual channel per physical channel. Give a one sentence rationale for your answer.
- D. Consider a Clos network with  $r=4$  input and output switches, each with  $n=2$  ports (for a total of  $nr = 8$  inputs and outputs). How many middle stages  $m$  are required for this network to be *strictly* non-blocking? What is the shape of each of these middle stages?

- E. True or False: Hop-by-hop routing generally results in a lower per-hop delay,  $t_r$ , than source routing. Give a one sentence rationale for your answer.
- F. True or False: Wormhole flow control generally requires larger buffers than store-and-forward flow control. Give a one sentence rationale for your answer.
- G. Consider a 64-node 8-ary 2-cube network. What must the bandwidth of each link in this network be to handle uniform random traffic with a bandwidth of 1Gbit/s from each input?
- H. Consider a topology with eight nodes in which node  $i$  is connected with bidirectional channels to four neighbors: nodes  $i \pm 1 \pmod{8}$  and  $i \pm 3 \pmod{8}$ . Give a bound on the ideal throughput of this topology on uniform random traffic (make your bound as tight as possible).

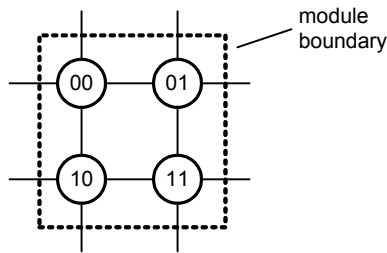
**2. Flow Control (20 points)**

Consider the following flow control method:

1. The head flit of the message is sent into the network.
  2. At each hop, the head flit allocates a physical for the packet and proceeds to the next hop. If the required physical channel is not available, the head flit waits until it is available.
  3. When the header reaches the destination, an acknowledgement is sent to the source.
  4. When the source receives the acknowledgement it transmits the remaining flits of the packet.
  5. As the tail flit of the packet passes each node, it deallocates the physical channel being held by the packet, freeing it for other packets.
- A. Draw a time-space diagram for this flow control method. Assume that the packet must traverse four hops and that the head flit blocks for two cycles after the second hop.
- B. How much buffering does this flow control method require at each node of the route?
- C. Compared to store-and-forward flow control, how does this flow control method compare in terms of (i) latency, (ii) throughput? (indicate higher or lower for each and give justification for your answer).

### 3. Topology (20 points)

- A. Select a torus topology ( $k$  and  $n$ ) and channel width ( $w$ ) for a 256-node network to maximize ideal throughput. Assume the nodes have a pin constraint of  $W_n = 128$  signals. There is no bisection constraint. Use a signaling frequency of  $f = 1$  Gbit/s, a packet length of  $L = 1024$ , and a router delay of  $t_r = 10$  ns. Ignore any wire and contention delay. If multiple topologies achieve the maximum throughput, choose the one with the lowest zero-load latency.



- B. Consider a module pin constraint where a number of nodes are packaged in a module and the total number of signals crossing the boundary of the module cannot exceed  $W_m$ . For example, as shown above four nodes are packaged in a single module as shown above and 16 channels (8 bidirectional channels) cross the boundary of this module. These 16 channels must all fit within the constraint of  $W_m$ . If we incorporate such a module constraint into the packaging problem of part (A), how would the throughput of the system be *qualitatively* changed, if at all? Would any components of zero-load latency be changed?

- C. Find a packaging of your network from part (A) given a module constraint of  $W_c = 1024$  signals. Also, no more than 64 nodes can be packaged in a single module. Minimize the number of modules required.

**4. Deadlock (20 points)**

Consider the zigzag routing algorithm for 2-dimensional mesh networks using wormhole flow control:

1. Compute the relative distances,  $\Delta x$  and  $\Delta y$ , between the source and destination nodes and a preferred direction vector  $D$  (e.g.  $\Delta x = 2$ ,  $\Delta y = 3$ , and  $D = (+, -)$  indicates a minimal route requires 2 hops in the  $+x$  direction and 3 hops in the  $-y$  direction).
  2. If  $\Delta x = 0$  and  $\Delta y = 0$ , end.
  3. If  $\Delta x > \Delta y$ ,
    - a. Move one hop in the  $x$  dimension's preferred direction (update current node).
    - b.  $\Delta x \leftarrow \Delta x - 1$ .
  4. Else,
    - a. Move one hop in the  $y$  dimension's preferred direction (update current node).
    - b.  $\Delta y \leftarrow \Delta y - 1$ .
  5. Go to step 2.
- A. Is the zigzag routing algorithm with wormhole flow control deadlock free? If not, use virtual channels to make it deadlock free, using as few virtual channels as possible.
- B. Consider a hybrid routing algorithm that uses zigzag routing when the preferred direction vector is  $D = (+, +)$  and dimension-order routing ( $x$  first, then  $y$ ) otherwise. Is this hybrid routing algorithm deadlock free with wormhole flow control?