Operating Systems 2024 Midterm Exam2 (2024/05/01)

1. (4%) Using Test-and-Set-Lock (TSL) instruction to implement mutex locks for MPs needs to lock the system bus. However, this may increase the bus contention. Please propose two methods to reduce the bus contention.
   Ans. (2% each)
   Read before TSL and TSL with back off.

2. (6%) What are Sender initiated Load Balancing and Receiver Initiated Load Balancing algorithms? Please give brief descriptions and compare their differences.
   Ans. (2% each)
   (a) SI-LB: pp65 of MC ppt
   (b) RI-LB: pp66 of MC ppt.
   (c) SI-LB does not perform well in heavily loaded situation and RI-LB does not degrade performance in heavily loaded situation.

3. (4%) Affinity scheduling reduces cache misses. Does it also reduce TLB misses? Does it reduce page faults?
   Ans. (2% each)
   (a) Affinity scheduling has to do with putting the right thread on the right CPU. Doing so might well reduce TLB misses since these are kept inside each CPU.
   (b) On the other hand, it has no effect on page faults, since in a MP, a page is either in physically shared RAM for all CPUs or in the backing storage.

4. (8%) What are the major pros and cons of master-slave multiprocessors? Please list 2 of them, respectively.
   Ans. (2% each)
   Pros:
   1. Easier to design and manage: Master-slave multiprocessors are easier to design and manage because there is only one processor that needs to be programmed and monitored.
   2. More efficient resource allocation: The master processor can allocate tasks to the slave processors, which can be beneficial for certain types of applications that require high levels of parallelism. Automatic load balancing.
   Cons:
   1. Limited scalability: Master-slave multiprocessors have limited scalability, as the performance of the system is heavily dependent on the performance of the master processor. The master may become performance bottleneck.

2. Single point of failure: Since the master processor is responsible for controlling the activities of the slave processors, if the master processor fails, the entire system may fail.

5. (4%) What are the number of switches for crossbar network and Omega network? Consider n CPUs and n memory modules
Ans. (2% each)
Crossbar: n^2
Omega: $\frac{n}{2}log_2n$

6. (6%) Please list and describe 3 types of transparency in a distributed system.
Ans. (2% each)
1. Access Transparency enables local and remote information resources to be accessed using identical operations.
2. Location Transparency enables resources to be accessed without knowing their actual locations.
3. Concurrency Transparency enables several processes to operate concurrently using the same shared resources without interference with each other.
4. Replication Transparency enables multiple instances of resources to be used to increase reliability and performance without knowledge of the replicas by users or applications.
5. Migration Transparency allows the movement of resources within a Distributed system without affecting the operations of users or applications.
6. Failure Transparency enables the concealment of faults. It allows users and applications to complete their tasks on the failure of some components.
7. Performance Transparency allows the DS and applications to be reconfigured on demand without changing the system structure or the application algorithms.

7. (4%) Please give 2 differences between the normal MPs and Chip-level MPs.
Ans. (2% each)
1. The shared L2 cache can affect performance. A greedy core may hold a lot of shared cache to hurt performance of other cores.
2. All CPUs of CMPs are so closely connected, shared component failures may bring down multiple CPUs at once.
3. MPs typically consist of multiple processors connected via a shared system bus, while chip-level MPs have multiple processors integrated on a single chip.
4. Scalability: MPs can be more scalable than chip-level MPs, as adding additional processors typically requires only the addition bus controllers, whereas adding

more processors to a chip can become more challenging due to physical space and heat constraints.

8. (4%) What makes blocking call a better way to message sending than non-blocking call in multithreaded system? Lists at least 2 reasons.
Ans. (2% each)
1. Simplicity: Blocking calls are simpler to use and reason about compared to non-blocking calls. With a blocking call, the calling thread can be sure that the message has been delivered before it continues executing, which can simplify the overall program logic.
2. Reduced Overhead: Non-blocking calls can generate more overhead since the calling thread needs to check the status of the message delivery operation repeatedly until it is complete. This overhead can be reduced with blocking calls since the calling thread is blocked until the message is delivered.
3. Better Resource Utilization (better concurrency): Blocking calls can lead to better resource utilization in a multithreaded system since threads can be blocked while waiting for messages to be delivered, allowing other threads to execute and use available resources.

9. (6%) Suppose that the wire between switch 2C and switch 3A in the omega network of Fig. 8-5 breaks. Who are cut off from whom?

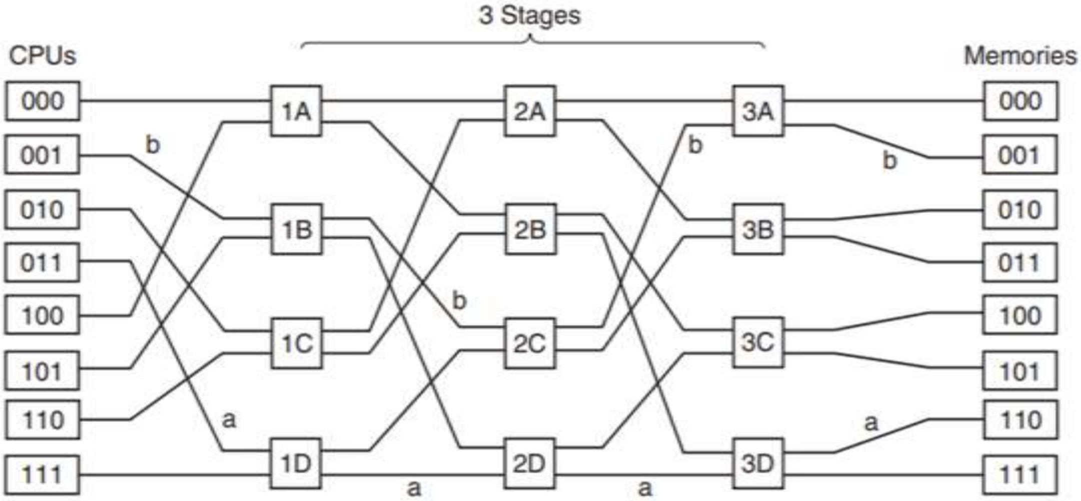


Figure 8-5. An omega switching network.

Ans. (1% each)
CPUs 001, 011, 101, 111 are cut off from Memories 000 and 001.

10. (6%) Use the omega network in the above, please give the routes for the following CPU memory pairs. (hint: CPU 000 -> 1A -> 2A -> 3A -> Memory 000)

(a) from CPU 010 to Memory 111
(b) from CPU 100 to Memory 100
(c) from CPU 111 to Memory 001
Ans. (2% each)
(a) 010->1C->2B->3D->111
(b) 100->1A->2B->3C->100
(c) 111->1D->2C->3A->001

11. (6%) For each of the topologies of Fig. 8-16, what is the diameter of the interconnection net-work? Count all hops (host-router and router-router) equally for this problem.

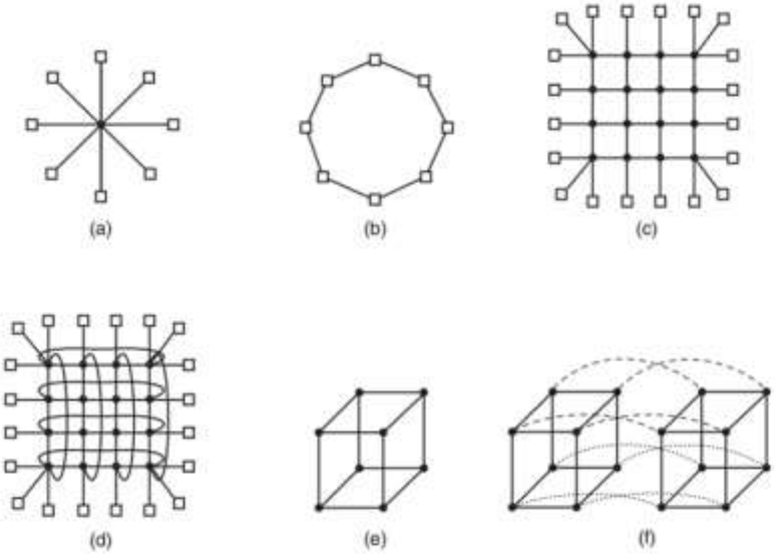
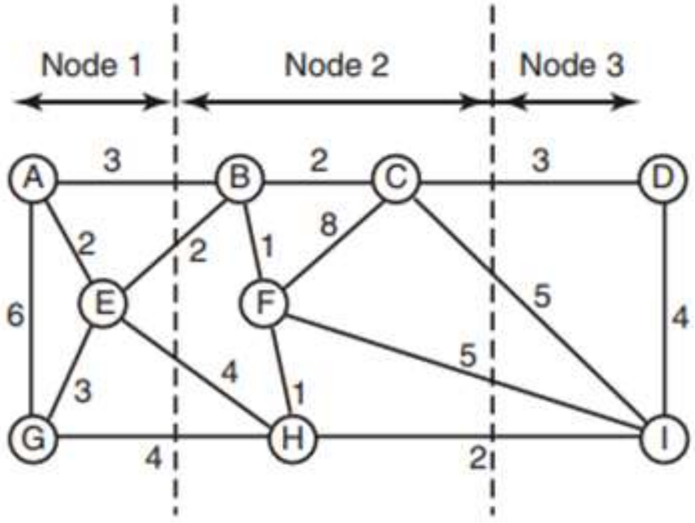


Figure 8-16. Various interconnect topologies. (a) A single switch. (b) A ring. (c) A grid. (d) A double torus. (e) A cube. (f) A 4D hypercube.

Ans. (1% each)
(a) 2 (b) 4 (c) 8 (d) 5 (e) 3 (f) 4

12. (6%) Please list and describe the 3 types of redundancy.
Ans. (2% each)
(1) Information Redundancy: it adds extra information to allow for error detection and recovery.
(2) Time Redundancy: it performs extra computations to cope with failures.
(3) Space Redundancy: it adds extra resources to cope with failures

13. (3%) Consider the processor allocation of the following figure. Suppose that process C and F are moved from node 2 to node 3. What is the total weight of the external traffic now?



Ans.

In this split, node 1 has A, E, and G, node 2 has B and H, and node 3 has C, D, F, and I. The cut between nodes 1 and 2 now contains AB, BE, EH and GH for a weight of 13. The cut between nodes 2 and 3 now contains BC, BF, FH, and HI for a weight of 6. The cut between nodes 1 and 3 now contains no edges. The total weight is 19.

14. (4%) Please describe the UMA and NUMA in the context of multi-processor systems?

Ans. (2% each)

1. In UMA, all processors share a common memory pool, and each processor can access any part of the memory with approximately the same latency. This means that the memory access time is uniform, regardless of which processor requests it.

2. On the other hand, NUMA allows each processor to have its own local memory, which it can access with lower latency compared to remote memory. This means that memory access time is not uniform and depends on the processor's location relative to the memory being accessed.

15. (6%) Describe how to implement a counting semaphore using the Linda system (You can use the following command: out, in).

Ans. (2% each)

Initialization: execute out(“sem”) N times.

wait(): in(“sem”)

signal(): out(“sem”)

16. (8%) Please give 4 possible methods for notifying a non-blocking receiver that the desired message has arrived.

    Ans. (2% each)

    (1). Interrupt the receiver when a message arrives.

    (2). The caller polls the status of the buffer periodically and retrieves the message when the state changes. Needs poll() and get_message() operations

    (3). On receiving a message, a pop-up thread is created to handle the message.

    (4). Process the arriving active message inside the interrupt handler. It only works in a completely trusted environment.

17. (6%) Please give 3 basic failuress may happen in message exchanges of client server model?

    Ans.

    (1). LostReq: Lost of request (Req) message

    (2). LostResp: Lost of response message (Resp)

    (3). SerCrash: Unsuccessful execution of the request

18. (4%) Please give brief descriptions about spin and block with context switch and provide in what scenarios it is appropriate to use spin and block with context switch in an SMP system, respectively.

    Ans. (2% each)

    1. Spin is a technique where a thread continuously polls a shared resource until it becomes available. In an SMP system, spin is appropriate when the wait time for a shared resource is expected to be short (or the number of threads contending for the resource is low.)

    2. Block with context switch is a technique where a thread yields the CPU and goes into a waiting state until the shared resource becomes available. In an SMP system, block with context switch is appropriate when the wait time for a shared resource is expected to be long (or the number of threads contending for the resource is high.)

19. (4%) Please describe the two common data transfer models in a Distributed File System.

    Ans. (2% each)

    1. in the download/upload model, the entire file is transferred from the server to the client machine before it is opened for use. It is appropriate when the file is small and the client machine has enough storage to store the entire file.

    2. in the remote access model, the file is transferred in smaller chunks as it is being accessed by the client machine. This mode is appropriate when the file is large, and the client machine has limited storage capacity.

20. (3%) In publish-subscribe systems, explain how channel-based approaches can be implemented using a group communication service?
    Ans.
    In a channel-based approach, events are published to a named channel and subscribers subscribe to a given channel and receive all messages sent on that channel. This can be implemented directly using group communication, that is when a channel is created, you create an associated group; subscriptions are implemented through joining the group and then subsequent events from publishers are sent to the group and hence delivered to all subscribers who are then members of the group.

21. (6%) Please list 3 major advantages of publish/subscription middleware model over the point to point model?
    Ans. (2% each)
    (a)Scalability: The pub/sub model is highly scalable, as new subscribers can be added without affecting the existing subscribers or publishers.
    (b)Decoupling: The pub/sub model provides a decoupled communication mechanism, where publishers and subscribers do not need to know about each other's existence, making the system more flexible and maintainable.
    (c)Asynchronous communication: The pub/sub model allows for asynchronous communication between publishers and subscribers, where messages can be delivered to subscribers even when they are not online.
    (d)many to many communications: The pub/sub model allows multiple publishers to communicate with multiple subscribers.