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QUESTION 1

What is concurrency in parallel and distributed computing?

ANSWER

Concurrency is the ability of a system to manage multiple tasks or processes at the same time, even though the tasks may not be running simultaneously. It allows overlapping execution of tasks to improve efficiency and resource utilization.

CC

QUESTION 2

Why is concurrency important in distributed systems?

ANSWER

It allows distributed systems to handle multiple operations simultaneously, improving performance and system responsiveness, especially when different processes need to coordinate or share resources across multiple nodes.

CC

QUESTION 3

How does concurrency differ from parallelism?

ANSWER

Concurrency involves handling multiple tasks at the same time but not necessarily executing them simultaneously. Parallelism, on the other hand, involves executing multiple tasks at the exact same time on different processors or cores.

CC

QUESTION 4

What is race condition in concurrent systems?

ANSWER

A race condition occurs when multiple processes or threads attempt to access and modify shared resources at the same time, leading to unpredictable outcomes. This happens because the processes "race" to execute without proper synchronization.

CC

QUESTION 5

What is a deadlock, and how does it occur in concurrent systems?

ANSWER

A deadlock occurs when two or more processes are waiting on each other to release resources, causing an indefinite wait. This often happens when processes acquire resources in different orders, leading to a circular dependency.

CC

QUESTION 6

How do locks help manage concurrency?

ANSWER

Locks are used to prevent multiple threads or processes from accessing the same resource simultaneously, ensuring that only one thread can modify the resource at a time. This helps prevent race conditions but can introduce issues like deadlocks or reduced performance.

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QUESTION 7

What is a thread in concurrent programming?

ANSWER

A thread is the smallest unit of a program that can execute independently. In concurrent programming, multiple threads can be created to perform tasks simultaneously, allowing a program to be more responsive and efficient.

CC

QUESTION 8

What role do scheduling algorithms play in concurrency?

ANSWER

Scheduling algorithms determine the order in which tasks are executed in a concurrent system. These algorithms aim to balance CPU utilization, responsiveness, and fairness among tasks to optimize system performance.

CC

QUESTION 9

What are some common synchronization techniques used in concurrent programming?

ANSWER

Common synchronization techniques include locks, semaphores, and monitors. These mechanisms help coordinate the execution of concurrent tasks, ensuring that shared resources are accessed in a controlled and consistent manner.

CC

QUESTION 10

What is the purpose of synchronization in a concurrent system?

ANSWER

The purpose of synchronization is to ensure that multiple threads or processes do not access shared resources simultaneously, which could lead to inconsistencies or data corruption. Synchronization ensures safe and orderly access to shared resources.

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MUTUAL EXCLUSION

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QUESTION 1

What is mutual exclusion in concurrent programming?

ANSWER

Mutual exclusion is a property that ensures only one process or thread can access a critical section or shared resource at a time, preventing race conditions and ensuring data consistency in concurrent programs.

CC

QUESTION 2

Why is mutual exclusion important in distributed systems?

ANSWER

Scheduling algorithms determine the order in which tasks are executed in a concurrent system. These algorithms aim to balance CPU utilization, responsiveness, and fairness among tasks to optimize system performance.

CC

QUESTION 3

What are locks, and how do they implement mutual exclusion?

ANSWER

Locks are synchronization mechanisms that prevent multiple threads or processes from entering the critical section at the same time. By "locking" the resource, a process ensures mutual exclusion, allowing only one process access at any given time.

CC

QUESTION 4

What is the difference between mutual exclusion and deadlock?

ANSWER

Mutual exclusion ensures that only one process can access a shared resource at a time. Deadlock, on the other hand, occurs when two or more processes are unable to proceed because they are each waiting for the other to release resources, creating an indefinite wait.

CC

QUESTION 5

What is a semaphore, and how does it help achieve mutual exclusion?

ANSWER

A semaphore is a synchronization primitive that can control access to a resource by maintaining a counter. For mutual exclusion, a binary semaphore (with values 0 and 1) ensures that only one process can access the resource at a time.

CC

QUESTION 6

What are the potential problems of using locks for mutual exclusion?

ANSWER

Problems with using locks include deadlock (where processes wait indefinitely for a lock), livelock (where processes keep changing state without making progress), and starvation (where a process never gains access to the resource because others are continuously locking it).

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QUESTION 7

What is a monitor, and how does it achieve mutual exclusion?

ANSWER

A monitor is a high-level synchronization construct that combines mutual exclusion and condition variables. It ensures that only one process or thread can execute a monitor procedure at a time, automatically providing mutual exclusion within the monitor's critical section.

CC

QUESTION 8

What is the "test-and-set" instruction, and how does it provide mutual exclusion?

ANSWER

The "test-and-set" instruction is an atomic operation used in hardware to implement mutual exclusion. It tests the value of a memory location and sets it if it was previously unset. This prevents other processes from entering the critical section while it is locked.

CC

QUESTION 9

What is a critical section, and how does mutual exclusion relate to it?

ANSWER

A critical section is a portion of a program where shared resources are accessed or modified. Mutual exclusion ensures that only one thread or process can execute the critical section at a time, preventing concurrent access that could lead to data corruption.

CC

QUESTION 10

What is Peterson's algorithm, and how does it achieve mutual exclusion?

ANSWER

Peterson's algorithm is a software-based solution for achieving mutual exclusion between two processes. It uses two shared variables, flag and turn, to ensure that only one process enters the critical section at a time, while the other waits for its turn.

PDC QUEST

CONSISTENCY IN STATE/MEMORY MANIPULATION

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CONSISTENCY IN STATE/MEMORY MANIPULATION

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QUESTION 1

What is consistency in distributed systems?

ANSWER

Consistency in distributed systems refers to the requirement that all nodes in the system see the same data at the same time. It ensures that when data is written or updated on one node, the changes are reflected across all other nodes to maintain a coherent state.

CM

QUESTION 2

What is the difference between strong and eventual consistency?

ANSWER

Strong consistency ensures that all nodes in the system see the same data immediately after a write operation. Eventual consistency, on the other hand, guarantees that, given enough time, all nodes will converge to the same state, but there may be a delay before the data is consistent across all nodes.

CM

QUESTION 3

What is the CAP theorem?

ANSWER

The CAP theorem states that in a distributed system, it is impossible to achieve Consistency, Availability, and Partition tolerance simultaneously. A system can only guarantee two out of these three properties. Consistency refers to ensuring all nodes see the same data after a write operation.

CM

QUESTION 4

What is the role of consistency models in memory manipulation?

ANSWER

Consistency models define the rules for how updates to shared memory or state are propagated and visible across different processes or nodes. These models ensure that multiple processes or nodes observe the same sequence of updates, providing a framework for managing shared data in a consistent manner.

CM

QUESTION 5

What is memory consistency in parallel computing?

ANSWER

Memory consistency in parallel computing refers to the order in which memory operations (such as reads and writes) appear to execute across multiple processors or cores. A memory consistency model ensures that all processors observe memory updates in a coherent way, so that the results of a program are predictable.

CM

QUESTION 6

How does eventual consistency benefit large-scale distributed systems?

ANSWER

Eventual consistency allows large-scale distributed systems to continue operating efficiently during network partitions or high loads. It sacrifices immediate consistency for availability and partition tolerance, allowing systems to remain responsive, with the guarantee that data will eventually become consistent across all nodes.

PDC QUEST

CONSISTENCY IN STATE/MEMORY MANIPULATION

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QUESTION 7

What is sequential consistency in memory operations?

ANSWER

Sequential consistency ensures that the result of executing operations (reads and writes) from multiple processors or threads is the same as if the operations were executed in some sequential order. In this model, all processors see the same order of operations, preserving program correctness in concurrent execution.

CM

QUESTION 8

What is the importance of state consistency in distributed systems?

ANSWER

State consistency is critical in distributed systems because it ensures that all nodes have a consistent view of the system's state, allowing reliable operation across different nodes. Consistent state enables accurate decision-making, transaction handling, and ensures that system behavior remains predictable.

CM

QUESTION 9

What is causal consistency, and how does it differ from strong consistency?

ANSWER

Causal consistency ensures that operations that are causally related are seen by all nodes in the same order, but operations that are not causally related may be seen in different orders. Strong consistency, by contrast, requires all operations to be seen in the same order across all nodes, regardless of causality.

CM

QUESTION 10

How do consistency levels affect the performance of distributed databases?

ANSWER

Stronger consistency levels, such as strong consistency, ensure that data is immediately synchronized across all nodes, but this can introduce significant latency and reduce system performance, especially in geographically distributed systems. Weaker consistency levels, like eventual consistency, reduce synchronization overhead, improving performance at the cost of delayed consistency.

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QUESTION 1

What is message-passing in parallel and distributed computing??

ANSWER

Message-passing is a communication method where processes exchange data by sending and receiving messages, facilitating coordination in systems without shared memory.

MP

QUESTION 2

What are the key differences between message-passing and shared memory approaches?

ANSWER

Message-passing allows processes to operate independently and communicate through explicit messages, whereas shared memory requires synchronization to manage concurrent access to a common memory space.

MP

QUESTION 3

What is the Message Passing Interface (MPI)?

ANSWER

MPI is a standardized message-passing system that enables communication between processes in parallel computing. It provides a set of library functions for managing data exchange across different systems.

MP

QUESTION 4

What are point-to-point and collective communication in message-passing?

ANSWER

Point-to-point communication involves direct message exchanges between two processes, while collective communication involves a group of processes, allowing operations like broadcasting and gathering data.

MP

QUESTION 5

What is the purpose of message buffers in message-passing systems?

ANSWER

Point-to-point communication involves direct message exchanges between two processes, while collective communication involves a group of processes, allowing operations like broadcasting and gathering data.

MP

QUESTION 6

What common operations are used in message-passing?

ANSWER

Common operations include send, receive, broadcast, scatter, gather, and reduce, which facilitate various patterns of data distribution and collection among processes.

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QUESTION 7

How does serialization relate to message-passing?

ANSWER

Serialization converts complex data structures into a format suitable for transmission over a network. It ensures that data can be accurately reconstructed at the receiving end.

MP

QUESTION 8

What are some typical challenges encountered in message-passing systems?

ANSWER

Challenges include latency, bandwidth limitations, deadlocks, message ordering issues, and the complexity of maintaining data consistency in distributed environments.

MP

QUESTION 9

How is error handling managed in message-passing frameworks?

ANSWER

Error handling often involves detecting failures, implementing retries, and using acknowledgment protocols to ensure messages are delivered reliably between processes.

MP

QUESTION 10

What role do communication protocols play in message-passing?

ANSWER

Communication protocols establish the rules for message formatting, error checking, and flow control, ensuring reliable and efficient data exchange between processes.

PDC QUEST

SHARED MEMORY MODELS

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SHARED MEMORY MODELS

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QUESTION 1

What is a shared-memory model in parallel and distributed computing?

ANSWER

A shared-memory model allows multiple processes to access a common memory space, enabling direct communication and data sharing without the need for explicit message-passing. This model simplifies programming but requires synchronization mechanisms to manage concurrent access.

SM

QUESTION 2

What are the primary advantages of using shared-memory models?

ANSWER

Advantages include ease of programming due to direct access to shared data, reduced communication overhead compared to message-passing, and better performance for applications that frequently access shared data.

SM

QUESTION 3

What synchronization mechanisms are commonly used in shared-memory models?

ANSWER

Common synchronization mechanisms include mutexes (mutual exclusions), semaphores, condition variables, and barriers. These tools help manage concurrent access and ensure data consistency.

SM

QUESTION 4

What are the challenges associated with shared-memory models?

ANSWER

Challenges include race conditions, where multiple processes access shared data simultaneously, leading to inconsistent results; deadlocks, where processes wait indefinitely for resources; and increased complexity in ensuring data integrity.

SM

QUESTION 5

How does the concept of a critical section relate to shared-memory programming?

ANSWER

A critical section is a portion of code that accesses shared resources and must not be executed by more than one process at a time. Proper management of critical sections is essential to prevent race conditions and ensure data consistency.

SM

QUESTION 6

What is the difference between coarse-grained and fine-grained locking?

ANSWER

Coarse-grained locking involves using a single lock for a large section of code or resource, which can lead to contention but is easier to implement. Fine-grained locking uses multiple locks for smaller sections of code or individual data items, reducing contention but increasing complexity.

PDC QUEST

SHARED MEMORY MODELS

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QUESTION 7

What role does memory consistency play in shared-memory systems?

ANSWER

Memory consistency defines the behavior of reads and writes in shared-memory systems, ensuring that processes see a consistent view of shared data. Different consistency models (e.g., sequential consistency, weak consistency) impact how memory operations appear to processes.

SM

QUESTION 8

How do atomic operations contribute to shared-memory programming?

ANSWER

Atomic operations are indivisible actions that complete in a single step from the perspective of other processes. They are crucial for implementing synchronization primitives and ensuring that operations on shared data are completed without interruption.

SM

QUESTION 9

What are the implications of cache coherence in shared-memory systems?

ANSWER

Cache coherence ensures that multiple caches in a shared-memory system reflect consistent values for shared data. Maintaining coherence can add complexity and performance overhead but is essential for ensuring correct program behavior.

SM

QUESTION 10

What is the role of thread libraries in shared-memory programming?

ANSWER

Thread libraries, such as POSIX Threads (pthreads), provide abstractions for managing multiple threads within a shared-memory environment. They offer tools for thread creation, synchronization, and management, simplifying parallel programming.

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SCALABILITY

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QUESTION 1

What is scalability in the context of parallel and distributed computing?

ANSWER

Scalability refers to the capability of a system to handle an increasing amount of work or its ability to be enlarged to accommodate that growth. In parallel and distributed computing, it often pertains to how well a system can maintain performance levels as the number of processes or nodes increases.

SC

QUESTION 2

What are the two main types of scalability?

ANSWER

The two main types of scalability are:

- Vertical Scalability (Scaling Up): Increasing the resources of a single node, such as adding more CPU or RAM.
- Horizontal Scalability (Scaling Out): Adding more nodes to a system to distribute the load.

SC

QUESTION 3

Why is scalability important in distributed systems?

ANSWER

Scalability is critical because it determines a system's ability to grow with increasing workloads. A scalable system can efficiently allocate resources, maintain performance levels, and manage costs as demand changes, which is essential for applications like cloud computing and large-scale data processing.

SC

QUESTION 4

What role does the architecture of a system play in its scalability?

ANSWER

The architecture determines how resources are organized and how processes communicate. Systems designed with scalability in mind, such as those using distributed architectures (like microservices), can more easily accommodate growth than monolithic architectures, which may face bottlenecks as they scale.

SC

QUESTION 5

What are some common scalability challenges in cloud computing?

ANSWER

Challenges include:

- Resource Management: Efficiently allocating resources to meet dynamic workloads.
- Data Consistency: Ensuring data remains consistent across distributed nodes as they scale.
- Latency: Managing the delays in communication as the system grows larger.

SC

QUESTION 6

How does Gustafson's Law differ from Amdahl's Law?

ANSWER

Gustafson's Law argues that the scalability of parallel computing systems can be better understood by considering the increase in problem size as more processors are added, rather than just focusing on speedup for a fixed problem size. It suggests that as we use more resources, we can take on larger problems, which can lead to better utilization of the available processors.

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QUESTION 7

Why is load balancing critical for scalability?

ANSWER

Load balancing is critical for scalability because uneven load distribution can lead to some nodes being overworked while others are idle, which can degrade overall performance and limit the effectiveness of scaling out.

SC

QUESTION 8

How can software design impact scalability?

ANSWER

Software design influences scalability through choices in algorithms, data structures, and system architecture. Well-designed software can exploit parallelism and minimize dependencies, allowing it to scale effectively. Conversely, poorly designed systems may introduce bottlenecks or unnecessary complexity that hampers scalability.

SC

QUESTION 9

How does the concept of "scale-out" relate to distributed computing?

ANSWER

"Scale-out" refers to adding more machines or nodes to a distributed system to handle increased load or data. It contrasts with "scale-up," which involves upgrading the existing hardware. Scale-out is often favored in cloud environments for its flexibility and cost-effectiveness.

PDC QUEST

SCHEDULING AND LOAD BALANCING

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QUESTION 1

What is scheduling in the context of parallel and distributed computing?

ANSWER

Scalability is critical because it determines a system's ability to grow with increasing workloads. A scalable system can efficiently allocate resources, maintain performance levels, and manage costs as demand changes, which is essential for applications like cloud computing and large-scale data processing.

SL

QUESTION 2

What is load balancing, and why is it important in distributed systems?

ANSWER

Load balancing is the process of distributing workloads evenly across multiple computing resources to ensure no single resource is overwhelmed while others are underutilized. This helps improve system responsiveness and resource utilization, leading to better overall performance.

SL

QUESTION 3

What are the common types of scheduling algorithms used in parallel computing?

ANSWER

Common scheduling algorithms include:

- First-Come, First-Served (FCFS)
- Round Robin (RR)
- Shortest Job Next (SJN)
- Priority Scheduling
- Multilevel Queue Scheduling

SL

QUESTION 4

How do static and dynamic scheduling differ?

ANSWER

Static scheduling assigns tasks to resources before execution, based on predefined criteria.

Dynamic scheduling, on the other hand, makes assignments during execution, allowing the system to respond to changes in workload and resource availability in real time.

SL

QUESTION 5

What is the role of heuristics in load balancing?

ANSWER

Heuristics are strategies used to make decisions about load distribution based on rules of thumb or empirical data rather than exhaustive calculations. They help to quickly determine efficient load-balancing configurations, especially in complex and dynamic environments.

SL

QUESTION 6

What are some challenges associated with load balancing in distributed systems?

ANSWER

- Resource heterogeneity: Different resources may have varying capabilities and performance.
- Dynamic workloads: The load on resources can change unpredictably over time.
- Communication overhead: Ensuring efficient communication between resources can introduce latency.
- Scalability: Balancing loads effectively as the number of resources increases can be complex.

PDC QUEST

SCHEDULING AND LOAD BALANCING

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QUESTION 7

What is a task graph, and how is it used in scheduling?

ANSWER

A task graph is a directed acyclic graph (DAG) that represents tasks as nodes and dependencies between tasks as edges. It is used in scheduling to visualize and optimize the execution order of tasks, ensuring that dependent tasks are scheduled appropriately.

SL

QUESTION 8

What is the concept of "makespan" in scheduling?

ANSWER

Makespan is the total time required to complete a set of tasks from the start of the first task to the finish of the last task. It is a common performance metric used to evaluate scheduling efficiency, with lower makespan indicating better performance.

SL

QUESTION 9

How does feedback-based scheduling work?

ANSWER

Feedback-based scheduling uses runtime information about task performance and resource utilization to adjust scheduling decisions dynamically. It allows the system to learn from past executions and improve future scheduling decisions, adapting to changing conditions.

SL

QUESTION 10

What is a decentralized load balancing approach?

ANSWER

Decentralized load balancing distributes the responsibility of load management among all nodes rather than relying on a central coordinator. Each node makes local decisions based on its load and the status of its neighbors, which can improve resilience and scalability.

PDC QUEST

SPEEDUP/ AMDAHL'S LAW

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QUESTION 1

What is speedup in the context of parallel computing?

ANSWER

Speedup is a measure of the improvement in performance of a parallel algorithm compared to its sequential counterpart. It is defined as the ratio of the time taken to complete a task using a single processor to the time taken using multiple processors.

SA

QUESTION 2

What is Amdahl's Law?

ANSWER

Amdahl's Law is a formula that describes the potential speedup of a task when using multiple processors. It states that the overall speedup of a program is limited by the fraction of the program that cannot be parallelized. The formula is given as S=1(1−P)+PNS = \frac{1}{(1 - P) + \frac{P}{N}} S=(1−P)+NP1, where SSS is the speedup, PPP is the parallelizable portion, and NNN is the number of processors.

SA

QUESTION 3

How does Amdahl's Law impact parallelization efforts?

ANSWER

Amdahl's Law highlights the diminishing returns of adding more processors. As the parallelizable portion increases, the potential speedup approaches a limit based on the non-parallelizable portion, which means that extensive parallelization may yield minimal improvements if a significant part of the workload remains sequential.

SA

QUESTION 4

What are the assumptions made by Amdahl's Law?

ANSWER

Amdahl's Law assumes that the non-parallelizable portion of a task remains constant regardless of the number of processors. It also assumes that there are no overheads related to managing parallel tasks and that all processors have equal performance.

SA

QUESTION 5

What is the difference between Amdahl's Law and Gustafson's Law?

ANSWER

Amdahl's Law focuses on fixed problem size and the limitations imposed by the non-parallelizable portion of a task. In contrast, Gustafson's Law argues that as more processors are added, the problem size can be scaled up, allowing for increased parallelization. Gustafson's Law suggests that speedup is more accurately reflected in scenarios where the workload is adjusted based on available resources.

SA

QUESTION 6

How can Amdahl's Law be applied to software optimization?

ANSWER

Amdahl's Law can guide developers in identifying bottlenecks in their code. By analyzing which portions of the code are parallelizable, developers can focus optimization efforts on those sections, potentially increasing the overall efficiency of the software.

PDC QUEST

SPEEDUP/ AMDAHL'S LAW

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QUESTION 7

What factors can lead to the violation of Amdahl's Law assumptions?

ANSWER

Factors include overhead from communication between processors, load balancing issues where some processors are idle while others are busy, and the presence of dynamic workloads that change as the program executes, leading to varying degrees of parallelizability.

SA

QUESTION 8

How can the limitations of Amdahl's Law be mitigated in practice?

ANSWER

To mitigate limitations, developers can optimize the parallel portions of their applications, reduce communication overhead, and implement better load balancing strategies to ensure that all processors are utilized effectively. Additionally, using techniques like task decomposition can enhance the parallelizable portions of a task.

SA

QUESTION 9

What is the significance of Amdahl's Law in the design of parallel computing systems?

ANSWER

Amdahl's Law serves as a fundamental principle that helps engineers and scientists understand the theoretical limits of speedup in parallel systems. It emphasizes the need to optimize both parallel and non-parallel sections of applications and informs decisions on how to architect systems for maximum efficiency.

SA

QUESTION 10

How can profiling tools assist in applying Amdahl's Law effectively?

ANSWER

Profiling tools help identify the time spent in various sections of code, allowing developers to quantify how much of the workload is parallelizable versus serial. This data is crucial for applying Amdahl's Law effectively, as it guides optimization efforts towards the parts of the code that will yield the most significant speedup.