Distributed Computing

- Distributed computing is a system where multiple computers work together to solve a problem, sharing resources, processing power, and data across a network.
- Unlike traditional computing, distributed systems do not rely on a single central server; instead, tasks are split among multiple machines.
- Tasks are divided into smaller subtasks and processed simultaneously across different computers, improving efficiency and speed.

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Distributed Computing

- Distributed systems are designed to handle failures gracefully; if one node fails, others can take over its tasks.
- These systems can expand by adding more nodes (computers), making them highly scalable for large-scale applications.
- Cloud computing uses distributed computing principles to provide computing resources, storage, and services over the internet.

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Distributed Computing

- Cloud platforms distribute workloads across multiple data centers and servers, ensuring optimal resource usage.
- Cloud computing dynamically scales resources up or down based on demand, a key benefit of distributed systems.
- Cloud-based platforms like **Amazon Web Services (AWS), Google Cloud, and Microsoft Azure** rely on distributed computing to provide seamless, high-availability services.

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Distributed vs Parallel Computing

Feature	Distributed Computing	Parallel Computing
Definition	Multiple computers (nodes) connected over a network, working together to solve a task.	Multiple processors within a single system working simultaneously on a task.
System Type	Loosely coupled (separate computers with independent memory).	Tightly coupled (shared memory or close interconnection).
Communication	Uses a network (LAN, WAN, or Internet) for communication between nodes.	Uses high-speed internal buses for fast data exchange.
Scalability	Highly scalable (more computers can be added easily).	Limited by the number of processors in the system.
Use Cases	Cloud computing, blockchain, web applications, and large-scale simulations.	Supercomputing, AI model training, real-time processing, and GPU-based tasks.

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Approaches to Parallel Computing

- Parallel computing involves breaking down tasks into smaller subtasks that can be executed simultaneously.

- **Task Parallelism (Functional Parallelism)**
  - Different tasks (or functions) execute simultaneously on different processors.
  - Example: In a web server, one thread handles database queries while another processes user requests.

- **Data Parallelism**
  - The same operation is performed on different subsets of data across multiple processors.
  - Example: Image processing, where different parts of an image are processed in parallel.

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Levels of Parallelism

- Parallelism can occur at different levels within a system.

- **Instruction-Level Parallelism (ILP)**
  - Multiple instructions from the same program are executed simultaneously.
  - Example: Modern CPUs use techniques

- **Thread-Level Parallelism (TLP)**
  - Multiple threads of a single process run in parallel.
  - Example: Multithreaded applications like web browsers where different tabs run on separate threads.

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Levels of Parallelism

- **Data-Level Parallelism (DLP)**
  - The same operation is applied to multiple data elements at once.
  - Example: Vector processing in GPUs

- **Task-Level Parallelism (TLP - High Level)**
  - Different tasks run in parallel, either within the same application or across multiple applications.
  - Example: A web server handling multiple client requests at the same time.

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Peer-to-Peer (P2P) Computing

- Peer-to-Peer (P2P) computing is a decentralized computing model where each computer (peer) acts as both a client and a server, allowing direct communication and resource sharing.
- Unlike traditional client-server models, P2P networks do not rely on a central server, making them more resilient to failures and censorship.
- Peers share resources such as files, processing power, bandwidth, or storage directly with one another.
- Open networks increase vulnerability to malware and unauthorized access.
- No centralized validation leads to potential data corruption.

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Cluster Computing

- Cluster computing is a system where multiple interconnected computers (nodes) work together as a single unit to perform computing tasks efficiently.
- All nodes in a cluster are connected through a high-speed network and share a common goal.
- A cluster has a central controller or management system that coordinates tasks across all nodes.

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Cluster Computing

- If one node fails, others can take over, making clusters highly reliable for critical applications.
- Supports parallel processing as tasks are divided among multiple nodes, allowing for faster computations and performance improvements.
- Scaling requires adding physical machines, which can be limited by infrastructure constraints.

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Grid Computing & Cloud

- Both grid computing and cloud computing rely on distributed systems where multiple computers work together to perform tasks.
- Grid computing enables the sharing of computing resources across multiple organizations, similar to how cloud computing shares resources on demand.
- Cloud computing uses virtualization to allocate resources ef ficiently, whereas grid computing aggregates physical resources across a network.

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Grid Computing & Cloud

- Cloud computing delivers on-demand services (IaaS, PaaS, SaaS), while grid computing focuses more on coordinating resources for large-scale processing.
- Cloud computing provides elastic scalability, grid computing allows organizations to combine computing power for high-performance computing (HPC).

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Grid Computing Vs Cloud

Feature	Grid Computing	Cloud Computing
Definition	A network of distributed computers working together to solve a problem.	On-demand access to computing resources over the internet.
Resource Management	Decentralized, resources are shared across multiple organizations.	Centralized, managed by cloud providers like AWS, Azure, Google Cloud.
Scalability	Limited by the number of connected computers.	Highly scalable, resources can be increased or decreased dynamically.
Usage Model	Best for scientific research, simulations, and large-scale computations.	Used for web hosting, SaaS, storage, and business applications.
Cost Model	Generally free or shared-cost among organizations.	Pay-as-you-go pricing model based on usage.

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Grid Computing Vs Cluster Computing

Feature	Grid Computing	Cluster Computing
Definition	A distributed network of independent computers working together to solve large problems.	A group of tightly connected computers working as a single system.
Geographical Location	Nodes are distributed across different locations and organizations.	Nodes are located in the same physical location (data center).
Resource Sharing	Uses heterogeneous (different) computing resources from multiple sources.	Uses homogeneous (similar) computers with shared resources.
Scalability	Highly scalable across multiple organizations.	Limited scalability, constrained by physical infrastructure.
Use Cases	Scientific research, large-scale simulations, and distributed computing.	High-performance computing (HPC), AI training, and database management.

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