**Introduction to Parallel Computing**

Before taking a toll on Parallel Computing, first, let’s take a look at the background of computations of computer software and why it failed for the modern era.

Computer software was written conventionally for serial computing. This meant that to solve a problem, an algorithm divides the problem into smaller instructions. These discrete instructions are then executed on the Central Processing Unit of a computer one by one. Only after one instruction is finished, next one starts.

A real-life example of this would be people standing in a queue waiting for a movie ticket and there is only a cashier. The cashier is giving tickets one by one to the persons. The complexity of this situation increases when there are 2 queues and only one cashier.

So, in short, Serial Computing is following:

1. In this, a problem statement is broken into discrete instructions.
2. Then the instructions are executed one by one.
3. Only one instruction is executed at any moment of time.

Look at point 3. This was causing a huge problem in the computing industry as only one instruction was getting executed at any moment of time. This was a huge waste of hardware resources as only one part of the hardware will be running for particular instruction and of time. As problem statements were getting heavier and bulkier, so does the amount of time in execution of those statements. Examples of processors are Pentium 3 and Pentium 4.

Now let’s come back to our real-life problem. We could definitely say that complexity will decrease when there are 2 queues and 2 cashiers giving tickets to 2 persons simultaneously. This is an example of Parallel Computing.

**Parallel Computing :**   
It is the use of multiple processing elements simultaneously for solving any problem. Problems are broken down into instructions and are solved concurrently as each resource that has been applied to work is working at the same time.

**Advantages** of Parallel Computing over Serial Computing are as follows:

1. It saves time and money as many resources working together will reduce the time and cut potential costs.
2. It can be impractical to solve larger problems on Serial Computing.
3. It can take advantage of non-local resources when the local resources are finite.
4. Serial Computing ‘wastes’ the potential computing power, thus Parallel Computing makes better work of the hardware.

**Types of Parallelism:**

1. **Bit-level parallelism –**  
   It is the form of parallel computing which is based on the increasing processor’s size. It reduces the number of instructions that the system must execute in order to perform a task on large-sized data.   
   *Example:* Consider a scenario where an 8-bit processor must compute the sum of two 16-bit integers. It must first sum up the 8 lower-order bits, then add the 8 higher-order bits, thus requiring two instructions to perform the operation. A 16-bit processor can perform the operation with just one instruction.
2. **Instruction-level parallelism –**  
   A processor can only address less than one instruction for each clock cycle phase. These instructions can be re-ordered and grouped which are later on executed concurrently without affecting the result of the program. This is called instruction-level parallelism.
3. **Task Parallelism –**  
   Task parallelism employs the decomposition of a task into subtasks and then allocating each of the subtasks for execution. The processors perform the execution of sub-tasks concurrently.

       4. **Data-level parallelism (DLP)** **–**  
Instructions from a single stream operate concurrently on several data – Limited by non-regular data manipulation patterns and by memory bandwidth

**Why parallel computing?**

* The whole real-world runs in dynamic nature i.e. many things happen at a certain time but at different places concurrently. This data is extensively huge to manage.
* Real-world data needs more dynamic simulation and modeling, and for achieving the same, parallel computing is the key.
* Parallel computing provides concurrency and saves time and money.
* Complex, large datasets, and their management can be organized only and only using parallel computing’s approach.
* Ensures the effective utilization of the resources. The hardware is guaranteed to be used effectively whereas in serial computation only some part of the hardware was used and the rest rendered idle.
* Also, it is impractical to implement real-time systems using serial computing.

**Applications of Parallel Computing:**

* Databases and Data mining.
* Real-time simulation of systems.
* Science and Engineering.
* Advanced graphics, augmented reality, and virtual reality.

**Limitations of Parallel Computing:**

* It addresses such as communication and synchronization between multiple sub-tasks and processes which is difficult to achieve.
* The algorithms must be managed in such a way that they can be handled in a parallel mechanism.
* The algorithms or programs must have low coupling and high cohesion. But it’s difficult to create such programs.
* More technically skilled and expert programmers can code a parallelism-based program well.

**Future of Parallel Computing:** The computational graph has undergone a great transition from serial computing to parallel computing. Tech giant such as Intel has already taken a step towards parallel computing by employing multicore processors. Parallel computation will revolutionize the way computers work in the future, for the better good. With all the world connecting to each other even more than before, Parallel Computing does a better role in helping us stay that way. With faster networks, distributed systems, and multi-processor computers, it becomes even more necessary.

# Hardware architecture (parallel computing)

Let’s discuss about parallel computing and hardware architecture of parallel computing in this post. Note that there are two types of computing but we only learn parallel computing here. As we are going to learn parallel computing for that we should know following terms.

1. **Era of computing –**  
   The two fundamental and dominant models of computing are sequential and parallel. The sequential computing era began in the 1940s and the parallel (and distributed) computing era followed it within a decade.
2. **Computing –**  
   So, now the question arises that what is computing?

Computing is any goal-oriented activity requiring, benefiting from, or creating computers. Computing includes designing, developing and building hardware and software systems; designing a mathematical sequence of steps known as an algorithm; processing, structuring and managing various kinds of information

1. **Type of Computing –**  
   Following are two types of computing :
   1. Parallel computing
   2. Distributed computing

**Parallel computing –**  
As in this article, we are going to learn Parallel computing so what is parallel processing?

Processing of multiple tasks simultaneously on multiple processors is called parallel processing. The parallel program consists of multiple active processes (tasks) simultaneously solving a given problem.

As we learn what is parallel computing and there type now we are going more deeply on the topic of the parallel computing and understand the concept of the hardware architecture of parallel computing.

**Hardware architecture of parallel computing –**  
The hardware architecture of parallel computing is disturbed along the following categories as given below :

1. Single-instruction, single-data (SISD) systems  
2. Single-instruction, multiple-data (SIMD) systems  
3. Multiple-instruction, single-data (MISD) systems  
4. Multiple-instruction, multiple-data (MIMD) systems

Refer to learn about the hardware architecture of parallel computing – [Flynn’s taxonomy](https://www.geeksforgeeks.org/computer-architecture-flynns-taxonomy/)

**Hardware computing –**  
Computer hardware is the collection of physical parts of a computer system. This includes the computer case, monitor, keyboard, and mouse. It also includes all the parts inside the computer case, such as the hard disk drive, motherboard, video card, and many others. Computer hardware is what you can physically touch.

### **What is distributed computing?**

Distributed computing is a model in which components of a software system are shared among multiple computers or nodes. Even though the software components may be spread out across multiple computers in multiple locations, they're run as one system. This is done to improve efficiency and performance. The systems on different networked computers communicate and coordinate by sending messages back and forth to achieve a defined task.

Distributed computing can increase performance, resilience and scalability, making it a common computing model in database and application design.

### **How distributed computing works**

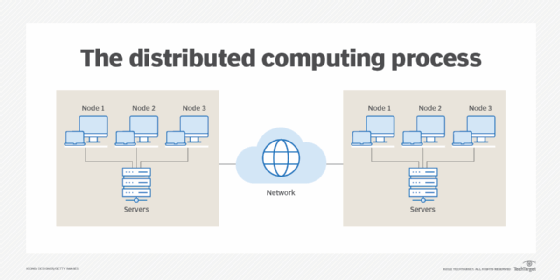
Distributed computing networks can be connected as local networks or through a [wide area network](https://www.techtarget.com/searchnetworking/definition/WAN-wide-area-network) if the machines are in a different geographic location. Processors in distributed computing systems typically run in parallel.

In enterprise settings, distributed computing generally puts various steps in business processes at the most efficient places in a computer network. For example, a typical distribution has a three-tier model that organizes applications into the presentation tier (or user interface), the application tier and the data tier. These tiers function as follows:

1. [User interface](https://www.techtarget.com/searchapparchitecture/definition/user-interface-UI) processing occurs on the PC at the user's location
2. Application processing takes place on a remote computer
3. Database access and processing algorithms happen on another computer that provides centralized access for many business processes

In addition to the three-tier model, other types of distributed computing include [client-server](https://www.techtarget.com/searchnetworking/definition/client-server), n-tier and peer-to-peer:

* **Client-server architectures.** These use smart clients that contact a server for data, then format and display that data to the user.
* **N-tier system architectures.** Typically used in application servers, these architectures use web applications to forward requests to other enterprise services.
* **Peer-to-peer architectures.** These divide all responsibilities among all peer computers, which can serve as clients or servers.

An example of how networks, servers and computers are structured in distributed computing.

### **Benefits of distributed computing**

Distributed computing includes the following benefits:

* **Performance.** Distributed computing can help improve performance by having each computer in a cluster handle different parts of a task simultaneously.
* **Scalability.** Distributed computing clusters are scalable by adding new hardware when needed.
* **Resilience and redundancy.** Multiple computers can provide the same services. This way, if one machine isn't available, others can fill in for the service. Likewise, if two machines that perform the same service are in different data centers and one data center goes down, an organization can still operate.
* **Cost-effectiveness.** Distributed computing can use low-cost, off-the-shelf hardware.
* **Efficiency.**Complex requests can be broken down into smaller pieces and distributed among different systems. This way, the request is simplified and worked on as a form of [parallel computing](https://www.techtarget.com/searchdatacenter/definition/parallel-processing), reducing the time needed to compute requests.
* **Distributed applications**. Unlike traditional applications that run on a single system, [distributed applications](https://www.techtarget.com/searchitoperations/definition/distributed-applications-distributed-apps) run on multiple systems simultaneously.

**Difference between Parallel Computing and Distributed Computing:**

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| --- | --- | --- |
| **S.NO** | **Parallel Computing** | **Distributed Computing** |
| 1. | Many operations are performed simultaneously | System components are located at different locations |
| 2. | Single computer is required | Uses multiple computers |
| 3. | Multiple processors perform multiple operations | Multiple computers perform multiple operations |
| 4. | It may have shared or distributed memory | It have only distributed memory |
| 5. | Processors communicate with each other through bus | Computer communicate with each other through message passing. |
| 6. | Improves the system performance | Improves system scalability, fault tolerance and resource sharing capabilities |