**Syllabus**

**UNIT 4 :Multi Core Architecture**

* 1. Cloud Computing Architecture
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  4. Parallel Programming
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Edge Computing Concepts

* 1. **Cloud Computing Architecture:**

Cloud Computing , which is one of the demanding technology of the current time and which is giving a new shape to every organization by providing on demand virtualized services/resources. Starting from small to medium and medium to large, every organization use cloud computing services for storing information and accessing it from anywhere and any time only with the help of internet. In this article, we will know more about the internal architecture of cloud computing.

Transparency, scalability, security and intelligent monitoring are some of the most important constraints which every cloud infrastructure should experience. Current research on other important constraints is helping cloud computing system to come up with new features and strategies with a great capability of providing more advanced cloud solutions.

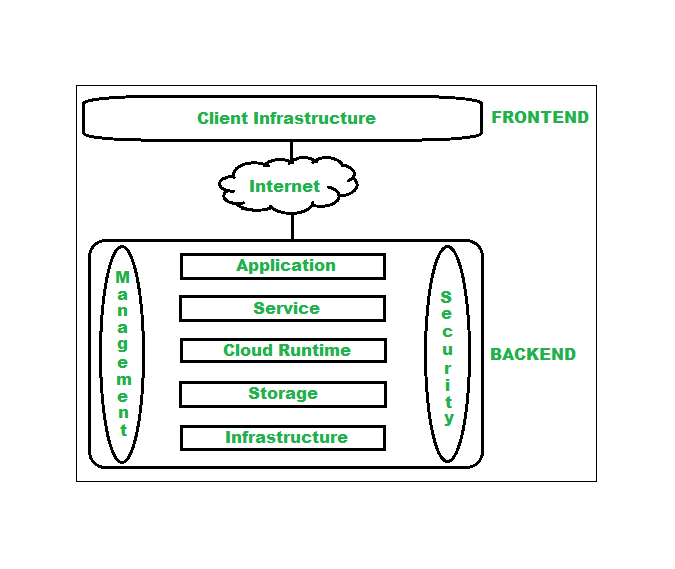
cloud computing technology is used by both small and large organizations to **store the information** in cloud and **access** it from anywhere at anytime using the internet connection.

Cloud computing architecture is a combination of **service-oriented architecture** and **event-driven architecture**.

**Cloud Computing Architecture :**  
The cloud architecture is divided into 2 parts i.e.

1. Frontend
2. Backend

The below figure represents an internal architectural view of cloud computing.



*Architecture of Cloud Computing*

Architecture of cloud computing is the combination of both [SOA (Service Oriented Architecture)](https://www.geeksforgeeks.org/service-oriented-architecture/) and EDA (Event Driven Architecture). Client infrastructure, application, service, runtime cloud, storage, infrastructure, management and security all these are the components of cloud computing architecture.

**1. Frontend :**  
Frontend of the cloud architecture refers to the client side of cloud computing system. Means it contains all the user interfaces and applications which are used by the client to access the cloud computing services/resources. For example, use of a web browser to access the cloud platform.

* **Client Infrastructure –** Client Infrastructure is a part of the frontend component. It contains the applications and user interfaces which are required to access the cloud platform.
* In other words, it provides a GUI( Graphical User Interface ) to interact with the cloud.

**2. Backend :**  
Backend refers to the cloud itself which is used by the service provider. It contains the resources as well as manages the resources and provides security mechanisms. Along with this, it includes huge storage, virtual applications, virtual machines, traffic control mechanisms, deployment models, etc.

1. **Application –**  
   Application in backend refers to a software or platform to which client accesses. Means it provides the service in backend as per the client requirement.
2. **Service –**  
   Service in backend refers to the major three types of cloud based services like [SaaS, PaaS and IaaS](https://www.geeksforgeeks.org/cloud-based-services/). Also manages which type of service the user accesses.
3. **Runtime Cloud-**  
   Runtime cloud in backend provides the execution and Runtime platform/environment to the Virtual machine.
4. **Storage –**  
   Storage in backend provides flexible and scalable storage service and management of stored data.
5. **Infrastructure –**  
   Cloud Infrastructure in backend refers to the hardware and software components of cloud like it includes servers, storage, network devices, virtualization software etc.
6. **Management –**  
   Management in backend refers to management of backend components like application, service, runtime cloud, storage, infrastructure, and other security mechanisms etc.
7. **Security –**  
   Security in backend refers to implementation of different security mechanisms in the backend for secure cloud resources, systems, files, and infrastructure to end-users.
8. **Internet –**  
   Internet connection acts as the medium or a bridge between frontend and backend and establishes the interaction and communication between frontend and backend.

**Benefits of Cloud Computing Architecture :**

* Makes overall cloud computing system simpler.
* Improves data processing requirements.
* Helps in providing high security.
* Makes it more modularized.
* Results in better disaster recovery.
* Gives good user accessibility.
* Reduces IT operating costs.

**Multi Core Architecture:**

Multicore refers to an architecture in which a single physical processor incorporates the core logic of more than one processor. A single integrated circuit is used to package or hold these processors. These single integrated circuits are known as a die. Multicore architecture places multiple processor cores and bundles them as a single physical processor. The objective is to create a system that can complete more tasks at the same time, thereby gaining better overall system performance.

This technology is most commonly used in multicore processors, where two or more processor chips or cores run concurrently as a single system. Multicore-based processors are used in mobile devices, desktops, workstations and servers.

The concept of multicore technology is mainly centered on the possibility of parallel computing, which can significantly boost computer speed and efficiency by including two or more central processing units (CPUs) in a single chip. This reduces the system's heat and power consumption. This means much better performance with less or the same amount of energy.

The architecture of a multicore processor enables communication between all available cores to ensure that the processing tasks are divided and assigned accurately. At the time of task completion, the processed data from each core is delivered back to the motherboard by means of a single shared gateway. This technique significantly enhances performance compared to a single-core processor of similar speed.

Multicore technology is very effective in challenging tasks and applications, such as encoding, 3-D gaming and video editing.

* 1. Multi Cloud Environment:
  2. What is Multi-Cloud?
  3. Multi-cloud is a model of cloud computing where an organization utilizes a combination of clouds—which can be two or more public clouds, two or more private clouds, or a combination of public, private and edge clouds—to distribute applications and services.
  5. **Multi-Cloud Use Cases**
  6. To accelerate the next phase of digital transformation, enterprises are taking advantage of multiple cloud platforms and services to:
  7. **Accelerate app transformation and the delivery of new apps:** Companies are choosing to deploy apps on public, private and edge clouds as it best suits their business objectives and application needs. Cloud First has been replaced by Cloud Smart.
  8. **Avoid vendor lock-in and ensure enterprise sovereignty:**Total cloud spend, data sovereignty, vendor dependencies and lock-in are increasing concerns. As a result, enterprises will continue to spread their estate across multiple environments.
  9. **Distribute applications and services to the edge:**In industries such as logistics, retail and manufacturing, the next generation of gains in automation, efficiency and improved customer experiences require applications to be distributed to the edge, closer to physical devices and users.
  10. **Support the rise of the distributed workforce:**Distributed workforces are the new reality for enterprises. Securing and managing users and their devices as well as enabling them to be productive from anywhere is the new hybrid workforce challenge.
  12. **Multi-Cloud Challenges**
  13. In the multi-cloud era, IT organizations face the challenge of supporting both existing and new application architectures and workloads across all major clouds, at the edge, in co-location facilities, in sovereign environments and in their private data center. Each cloud provider, with its own operating stack, services and toolsets, delivers a unique set of capabilities that do not extend functionality to other cloud platforms. This inconsistency in cloud infrastructure and operating models places a strain on technology personnel, decentralizes IT services, and introduces complexity and risk into the environment.
  14. **Both IT and Developers cite numerous pain points in the successful operationalization of multi-cloud:**
  15. **Inconsistent infrastructure:**Without a consistent multi-cloud infrastructure that spans all environments, cloud operational teams work in silos, with little flexibility to change strategies quickly or easily in response to changing business needs.
  16. **An ever-changing application landscape:** To support the faster release of new apps or features that deliver digital business value, organizations need to support the growing complexity of both existing and new application architectures, ensuring they can support DevSecOps, performance and availability across multiple cloud environments.
  17. **Inefficient management:** Lack of efficient and consistent multi-cloud infrastructure and management tools across diverse cloud environments significantly increases costs while exposing major security gaps.
  18. **Networking and security:**Networking and securing applications and data across clouds is complex, contributing to holes in security, risk exposure and an increased attack surface.
  19. **A distributed workforce:** With more data and people outside of the network, enterprises struggle to enable choice, flexibility, and a streamlined user experience without jeopardizing security.
  20. **Multi-Cloud Services**
  21. Multi-cloud services is an emerging category of software services in response to multi-cloud challenges. A multi-cloud service standardizes one or more functional areas across clouds with a consistent API, object model, identity management and other core functions and has one or more of the following characteristics:
  22. Runs on a single cloud but supports interactions with at least two different clouds
  23. Runs on multiple clouds and supports interactions with at least two different clouds
  24. Runs on a cloud or edge of a user’s choosing, even in disconnected mode, and basic operations are fully automated
  25. A multi-cloud service abstracts functionality into one platform and reduces complexity compared to individually consuming the equivalent native services from multiple clouds. In this model, the public clouds and data center and edge locations are all “verticals” and the multi-cloud services are “horizontal”, providing functionality across these locations. Multi-cloud services extend and complement the native services on each cloud, while also providing consistency across clouds.
  26. **Common functions provided by a multi-cloud service include:**
  27. **Application services:** databases, messaging, AI/ML, serverless, CI/CD, dev tooling, and more
  28. **Infrastructure services:** core compute, storage, and network services presented through virtual machines or containers accessed via self-service. Infrastructure-as-a-Service (IaaS) platforms include infrastructure automation and Kubernetes solutions
  29. **Security services:** network detection and response (NDR), endpoint detection and response (EDR), next-gen anti-virus (NGAV), SASE, and more
  30. **End-user services:** virtual desktop, mobile device management, end-user application delivery, and more
  31. **Data plane services:** workloads and data that create applications, business analytics, and business offerings

**Benefits of Multi-Cloud Services**

Organizations see many benefits when leveraging multi-cloud services to abstract core services offered by cloud providers. These include:

* Reduced operational overhead by managing applications and infrastructure with the same toolsets across clouds. This includes the creation of “skill portability” where developers and operators can use the same skills across multiple cloud platforms
* Improved observability at all layers consistently across clouds, which in turn can improve application performance and security
* Enhanced security posture by leveraging a Zero Trust architecture and secure software supply chains
* Increased application portability opportunities via consistent services and APIs
* Choice of best of breed cloud native services
  1. **Parallel Programming:**

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.
  1. **Parallel Processing:**

# Parallel Processing

Parallel processing can be described as a class of techniques which enables the system to achieve simultaneous data-processing tasks to increase the computational speed of a computer system.

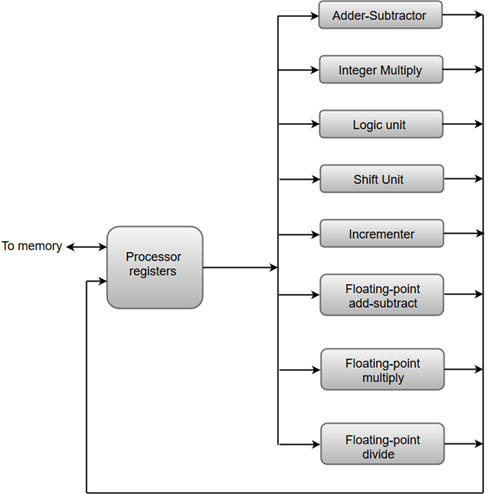
A parallel processing system can carry out simultaneous data-processing to achieve faster execution time. For instance, while an instruction is being processed in the ALU component of the CPU, the next instruction can be read from memory.

The primary purpose of parallel processing is to enhance the computer processing capability and increase its throughput, i.e. the amount of processing that can be accomplished during a given interval of time.

A parallel processing system can be achieved by having a multiplicity of functional units that perform identical or different operations simultaneously. The data can be distributed among various multiple functional units.Play Vide

The following diagram shows one possible way of separating the execution unit into eight functional units operating in parallel.

The operation performed in each functional unit is indicated in each block if the diagram:



* The adder and integer multiplier performs the arithmetic operation with integer numbers.
* The floating-point operations are separated into three circuits operating in parallel.
* The logic, shift, and increment operations can be performed concurrently on different data. All units are independent of each other, so one number can be shifted while another number is being incremented.

# What is edge computing?

An edge computing environment distributes and manages workloads beyond the data center or cloud, in or near the locations where an enterprise conducts business

Edge computing is about placing computer workloads (both hardware and software) as close as possible to the edge—to where the data is being created and where actions are occurring. Edge computing environments give customers faster response times, greater data privacy, and reduced data transfer costs.

What is Edge Compute?

Edge compute is the data processing that takes place at the network edge to decrease latency and reduce demands on cloud compute and data center resources. Edge computing takes place in intelligent devices — right at the location where sensors and other instruments are gathering and processing data — to expedite that processing before devices connect to the Internet of Things (IoT) and send the data on for further use by enterprise applications and personnel.

The primary reason for the growth of edge compute is efficiency. All of that collected data needs to be processed somewhere. And as the volume of IoT data has increased, more and more of the processing is taking place at the edge. Connected devices today are smarter, enabling the ability to program "edge AI" — artificial intelligence at the edge — a growing trend in edge intelligence.

With decades of experience in the rapidly evolving IoT industry, Digi has a complete product offering for optimizing IoT applications with edge compute functionality.

As small, inexpensive, and networking-capable computers become more powerful, edge computing will become more pervasive in all sectors of the economy.

* For telecommunications providers, edge computing environments allow customers to run workloads in their multi-access edge computing (MEC) facilities that are embedded in local communities.
* For farmers, edge computing means monitoring growing conditions on a much finer scale to more precisely act and increase yields.
* For retailers, edge computing means they can manage the lifecycles of their broad-ranging workloads on devices of many types and architectures across multiple store locations.
* For manufacturers, edge computing environments allow them to use a modern cloud-native style of development and deployment while remaining "air-gapped" (completely disconnected) from the internet.

### Benefits of edge computing

True to its name, edge computing takes compute out of an enterprise's core data center and places it close to endpoint devices where data is being generated, which brings several key benefits, such as:

#### 1. Improved speed/reduced latency

* By its definition and design, edge computing eliminates the need to move data from endpoints to the cloud and back again. Decreasing that travel shaves time off the entire process; this time savings can be measured in seconds, sometimes even milliseconds. That might not seem like much, but travel time -- known as latency -- is a critical consideration in a connected world where real-time decision-making capabilities are necessary for proper functioning of the endpoint devices.
* For example, autonomous vehicles, industrial and [manufacturing IoT deployments](https://internetofthingsagenda.techtarget.com/feature/Reap-the-rewards-of-IT-OT-convergence-in-manufacturing) and medical use cases all require machines to analyze data and return instructions nearly instantaneously in order to function safely.

#### 2. Improved security and privacy protections

* Edge computing can provide enhanced security and more privacy protections because it keeps data close to the edge and thus out of centralized servers. Edge devices are still vulnerable to being hacked, particularly if they're not adequately protected. However, edge devices hold very limited amounts of data and often not complete data sets that could be used by hackers.
* On the other hand, endpoint data stored in centralized servers tends to be combined with other data points that then creates a more complete collection of information that hackers could use for nefarious purposes. Consider, for example, edge computing in a healthcare setting. Sensors collect a patient's vital signs, which are then analyzed by an edge computing device. That device only holds those readings.
* However, if the endpoint sensors send the data back to centralized servers where it's stored with other information, including [personally identifiable information](https://www.techtarget.com/searchsecurity/definition/personally-identifiable-information-PII) about the patient, and that information is hacked, then that patient's privacy is compromised.

#### 3. Savings/reduced operational costs

* Although [data storage costs](https://www.techtarget.com/searchstorage/tip/Calculate-HPC-storage-costs-based-on-these-8-factors) have dropped significantly in the past decade or so, the cost of moving data around is on the rise as the volume of it increases. Experts expect connectivity costs to continue climbing as the volume of data spikes. They also expect that users will need to implement more bandwidth to handle the load, further driving up the price tag.
* Edge computing can help keep costs in check, or at least from climbing as high as they could, by reducing the amount of data being moved back and forth to the cloud.

#### 4. Reliability and resiliency

* Edge computing continues to operate even when communication channels are slow, intermittently available or temporarily down. For example, an energy company with edge computing deployments on an oil rig doesn't have to constantly rely on an available satellite connection to relay data back to a data center for processing; it can opt instead to move only the necessary processed information from the edge back to its data center when the connection is available.
* Edge computing further enhances resiliency by reducing a central point of failure -- as is the case with centralized servers; a failure at one edge device won't affect the performance of other edge devices in the ecosystem, thereby improving the reliability of the entire connected environment.

#### 5. Scalability

* [Like cloud computing](https://internetofthingsagenda.techtarget.com/tip/Comparing-edge-computing-vs-cloud-computing), organizations can add edge devices as they expand their uses so that they're deploying and managing only what they need. Additionally, endpoint hardware and edge devices often cost less than adding more computing resources within a centralized data center -- thereby making it more efficient for organizations to scale at the edge.

### Edge Computing in Action — Use Cases

The huge expansion of IoT has driven a corresponding expansion in edge computing capabilities and use cases. The following represent just a fraction of the growing spectrum of edge computing applications.

* **Manufacturing**: Adaptive diagnostics in an industrial setting can be improve the uptime of machines and equipment, cutting service expenses. Edge-compute-generated error codes, combined with historical repair information can provide context for technicians, speeding up troubleshooting and repairs.
* **Smart Cities**: Edge compute enables public buildings and facilities to be monitored for greater efficiency in lighting, heating and more. In traffic management applications, cameras and signals can improve safety and traffic flow. In the near future, autonomous vehicles, where near-zero latency is critical, will be the most visible and dramatic examples of real-time edge computing.
* **Healthcare**: Wearable devices can store information on heart rate, temperature, and other metrics, then provide reminders for medication. In addition, edge computing enables developers to ensure sensitive data, such as medical imagery, does leave the device to enhance security and privacy.