Chap 01

Introduction to Edge Computing and IoT

What Is Edge Computing:

“Edge computing is a distributed IT architecture which moves computing resources from clouds and data centres as close as possible to the originating source.”

The main goal of edge computing is to reduce latency requirements while processing data and saving network costs.

Edge Computing is a distributed computing architecture that brings computing and data storage closer to the source of data.

- Data processing takes place at the network’s edge, adjacent to the device that generated the data, as opposed to a central location, such as a data center.
- Reduced latency and bandwidth needs are desired outcomes of edge computing when transferring large amounts of data to a processing center.
- Edge computing facilitates real-time decision-making by processing data close to the edge and accelerating data transfer to and from the cloud.

What is the significance of Edge Computing in IoT:

Edge computing plays a significant role in the Internet of Things (IoT) ecosystem by addressing several critical challenges and enabling enhanced capabilities. Its importance in IoT stems from its ability to process and analyze data closer to its source, resulting in reduced latency, improved efficiency, and better utilization of network resources. Here's the significance of edge computing in IoT:

***Low Latency and Real-Time Processing*:**

Edge computing allows data processing and analysis to occur at or near the edge devices themselves. This reduces the time it takes for data to travel to a centralized cloud server and back. In applications such as industrial automation, healthcare monitoring, and autonomous vehicles, low latency is crucial for real-time decision-making and immediate responses.

Bandwidth Optimization:

IoT devices can generate massive amounts of data. Transmitting all this data to a central cloud for processing can strain network bandwidth and lead to increased costs. Edge computing minimizes the volume of data sent to the cloud by performing preliminary analysis and filtering at the edge, sending only relevant or summarized data to the cloud.

Data Privacy and Security:

Many IoT applications involve sensitive data. Edge computing allows organizations to process and store sensitive data locally, reducing the risk of exposing it over potentially insecure networks during transit to the cloud. This enhances data privacy and security compliance.

Offline Operation:

Edge devices can operate independently of a continuous network connection. In scenarios where network connectivity is intermittent or unreliable, edge computing ensures that devices can continue processing data and making decisions even when disconnected from the cloud.

Scalability and Distribution:

Edge computing enables the distribution of computational resources across various locations. This is particularly useful for applications that require processing capabilities at multiple points of data generation, such as smart cities, manufacturing plants, and large-scale sensor networks.

Reduced Cloud Load and Costs:

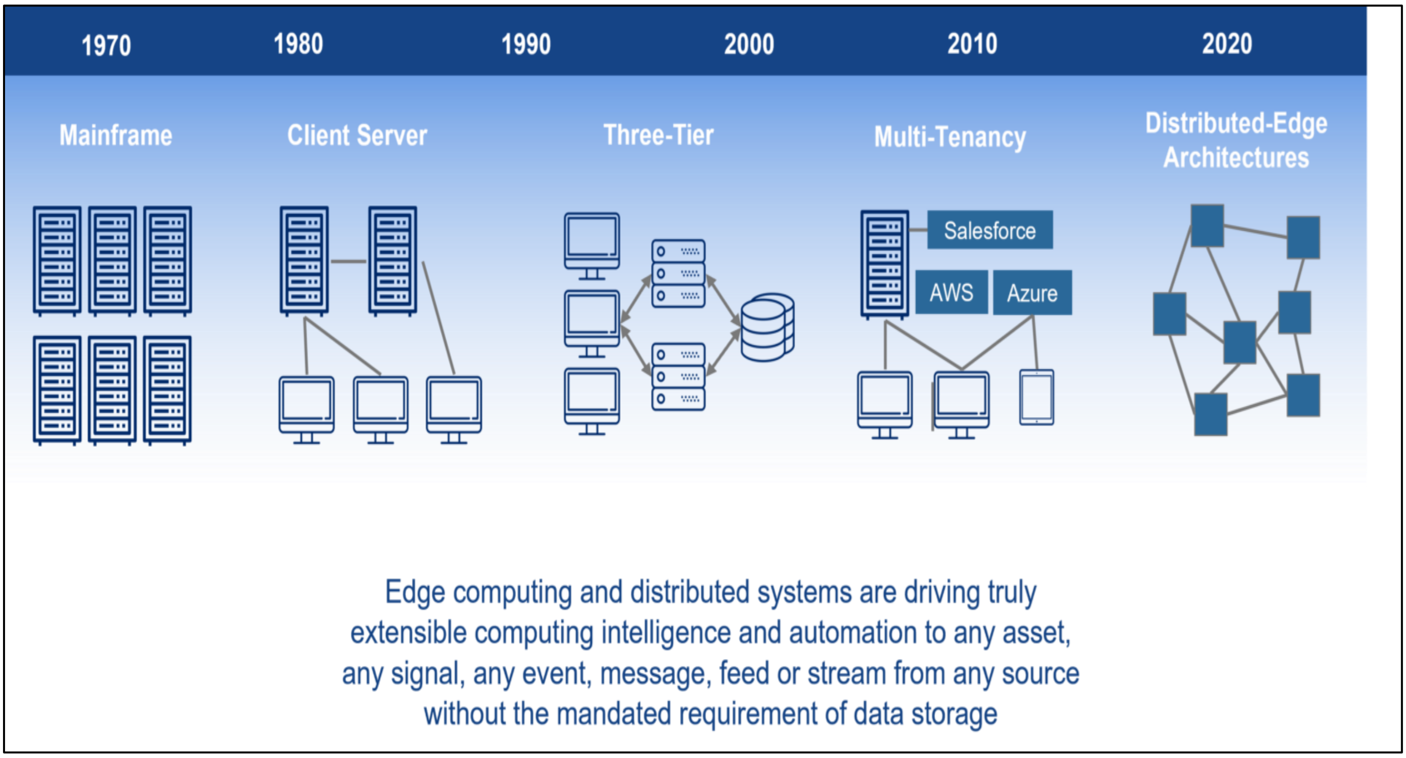
By offloading some processing tasks to edge devices, the load on centralized cloud servers is reduced. This optimization can lead to cost savings in terms of cloud infrastructure and data transfer expenses.

☣ Benefits of Edge Computing

There are many benefits of edge computing as it targets problems in the existing infrastructure:

1. **Autonomy:** It processes data on a local network reducing the sheer amount of data that needs to be sent and received. This means you need less bandwidth and connectivity time.
2. **Data jurisdiction:** By keeping data close to the source, there are fewer problems associated with the crossing of national borders, boundaries, and sovereign laws. This means that edge computing creates fewer legal issues, including security and privacy.
3. **Security:** Edge deployment allows data to be encrypted when it travels to the cloud or to the data center. Also, edge computing can be strengthened against cybercrime, such as hacking. This is even possible if the IoT devices are limited in terms of security capability.
4. **Minimal latency:** Due to processors being available close to where the data will be used improves processing time. It also enables real-time analytics. The opportunities for new markets are exponential.
5. **Simplified maintenance:** Micro-data centers (µDC) are tiny, can be transported on the back of a truck, and are created with as much accessibility and modularity as possible.
6. **Reduced cooling costs:** Large data centers can cost a lot to cool. However, cooling a range of smaller data centers could cost a lot less, at least in theory.
7. **Climate consciences:** It is possible that many smaller data centers will use less energy than one huge data center if edge could appropriately maximize accuracy and efficiency within its computerizations.

⚛ Evolution of EDGE COMPUTING:



What are the key challenges of edge computing?

Network Bandwidth

In traditional networks, enterprises would allocate higher bandwidth at central data centres and lower bandwidth to the endpoints. Whereas, in an edge computing server, more bandwidth is required across all individual ends of the server. This creates a need for more bandwidth when compared to the traditional networks.

Solution: As per the current scenario, the Edge Computing server needs to allocate higher bandwidth to data centres as well as endpoints therefore, the edge server requires comparatively more bandwidth than the traditional network which, in turn, leads to excessive consumption of data.

This patent provides a unique Control Delivery Network (CDN) in which each edge server is marked with a fixed threshold value of bandwidth consumption.

Distributed Computing

Due to the limited processing capacity, a large number of distributed edge nodes cannot provide all services completely and independently and need to cooperate with other edges or cloud data centers through an optical transport network which itself needs to provide a large number of routes to fulfill the requirements of distributed edge node in areas like autonomous cars and blockchain.

This invention suggests to breaks down the entire edge server into multiple routes with route arranging devices located at the edge center. On receiving a connection request, the appropriate route is searched (by matching source and destination node requirements) and if not found, a new route is formed as per the service and bandwidth requirements.

Latency

Latency is essentially the delay caused by data transmission. In an edge server, if the computation is taking place closer to data or if the compute is only happening at the center, latency can be reduced. But usually, due to distributive computing and both-ways computation, latency issues occur.

Solution

This invention suggests that by analysing network architecture comprising of an edge data center and edge nodes, programmatically expected latency associated with both node and core can be determined. After this, the difference between the latency of both can be devised out on basis of which, the edge transfer process can be optimized.

Data Management and Scalability:

Challenge: Managing data generated by numerous edge devices and ensuring data consistency, synchronization, and scalability can be complex.

Solution: Use data management strategies like data synchronization protocols and distributed databases. Implement data partitioning and intelligent data filtering to reduce the volume of data sent to the cloud.

Security and Privacy:

Challenge: Securing edge devices is challenging due to their distributed nature and potential exposure to physical attacks. Data privacy concerns can arise when processing sensitive information at the edge.

Solution: Implement robust security measures, including encryption, authentication, and access controls. Use hardware-based security solutions such as Trusted Platform Modules (TPMs). Apply data anonymization and aggregation techniques to protect privacy.

☯Advantage and Disadvantage of Edge Computing:

Advantages:

- It offers high speed, reduced latency better reliability which allows for quicker data processing and content delivery.
- It offers better security by distributing processing, storage, and applications across a wide range of devices and data centers, which makes it difficult for any single disruption to take down the network.
- It offers a far less expensive route to scalability and versatility, allowing companies to expand their computing capacity through a combination of IoT devices and edge data centers.
- In cases of intermittent connectivity and constrained bandwidth brought on by remote places, such as forests or sailing vessels, edge computing is beneficial.

Disadvantages:

- It requires more storage capacity.
- Security challenges in edge computing is high due to huge amount of data.
- It only analyse the data.
- Cost of edge computing is very high.
- It requires advanced infrastructure.

💟Explain the different applications (Example or use case) of Edge computing.

Edge computing has a wide range of applications across various industries and use cases. Its ability to process data locally and provide real-time insights makes it suitable for scenarios where low latency, efficient data processing, and immediate decision-making are essential. Here are some different applications of edge computing:

Industrial Automation and Manufacturing:

- Edge computing enables real-time monitoring, control, and optimization of industrial processes.
- Applications include predictive maintenance, quality control, process optimization, and robotics control.
- Reduces downtime, increases efficiency, and enhances overall production operations.

Smart Cities:

- Edge computing supports various smart city initiatives, including traffic management, public safety, waste management, and energy optimization.
- Enables real-time analysis of data from sensors, cameras, and other IoT devices for improved urban management.

Healthcare:

- Edge computing facilitates remote patient monitoring, real-time diagnostics, and personalized treatment.
- Enables wearable health devices, telemedicine, and instant transmission of critical patient data to healthcare providers.

Autonomous Vehicles:

- Edge computing processes data from sensors and cameras in autonomous vehicles for real-time decision-making.
- Critical for ensuring safety and responsiveness in self-driving cars and drones.

Energy and Utilities:

- Edge computing optimizes energy consumption by monitoring and controlling equipment in real time.
- Supports applications like smart grid management, renewable energy integration, and predictive maintenance for utility infrastructure.

Agriculture:

- Edge computing aids precision agriculture by monitoring soil conditions, weather, and crop health.
- Enables real-time decision-making for irrigation, pest control, and crop management.

Telecommunications:

- Edge computing enhances the performance of 5G networks by processing data closer to users.
- Supports applications like augmented reality, virtual reality, and ultra-low latency communication.