Session -3 : 9th August 2025

Enabling Techniques:

1. Edge Analytics & AI:

- **Edge Analytics:**

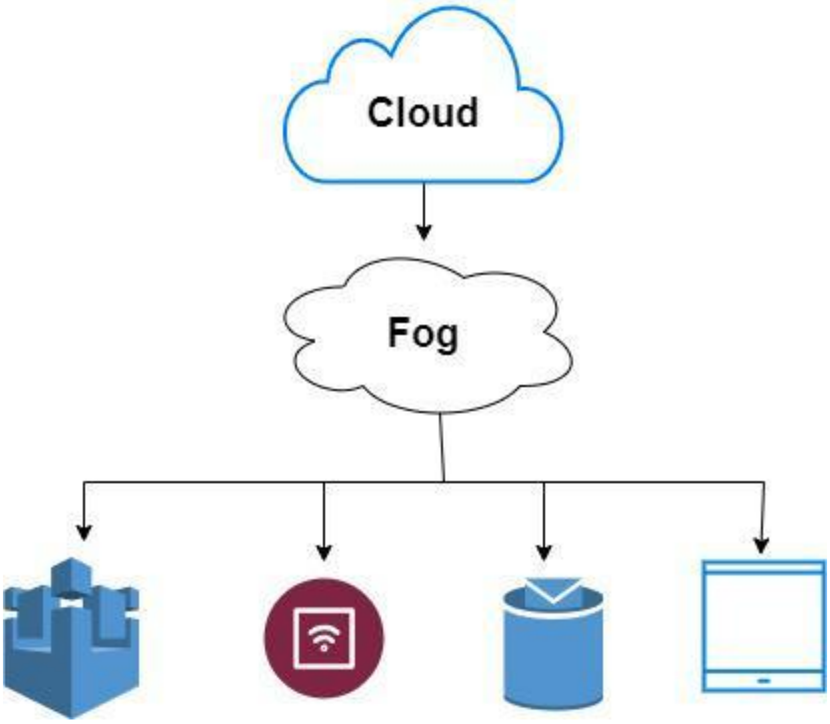
This involves processing data directly on edge devices (like sensors, cameras, or gateways) to extract valuable insights in real-time. This reduces latency and bandwidth usage by minimizing the need to send raw data to the cloud.

- **Edge AI:**

Leveraging artificial intelligence and machine learning models on edge devices enables more intelligent decision-making at the edge. This can range from simple tasks like filtering data to complex tasks like object recognition or predictive maintenance.

2. Fog Computing:

- Fog computing acts as an intermediary layer between edge devices and the cloud, providing more processing power and storage capacity than simple edge devices. It allows for more complex analytics and data aggregation closer to the edge, further reducing reliance on the cloud.
- Fog nodes can be located in various places, such as local servers, routers, or even dedicated fog computing devices, offering flexibility in deployment.



3. Wireless Technologies:

- **5G and Wi-Fi 6:** These technologies offer higher bandwidth and lower latency, making them ideal for supporting data-intensive applications at the edge, such as autonomous vehicles and augmented reality.
- Improved wireless connectivity enables seamless data transfer and communication between edge devices and other network components.

4. Infrastructure and Orchestration:

- **Infrastructure Optimization:**

This involves designing and deploying edge computing infrastructure (servers, storage, and networking equipment) in a way that is efficient, scalable, and optimized for specific edge use cases.

- **Orchestration:**

This refers to the management and automation of edge resources and deployments. It ensures that applications and services are deployed and managed efficiently across the edge network.

- **Traffic Routing:**

Efficiently directing data traffic to the most appropriate edge location or cloud resource is crucial for performance and resource utilization.

5. Security and Privacy:

- **Secure Data Handling:**

Edge computing environments require robust security measures to protect sensitive data, especially when dealing with personal or financial information. This includes encryption, access control, and other security protocols.

- **Privacy Considerations:**

Edge deployments need to comply with privacy regulations and ensure that user data is handled responsibly.

6. Other Key Aspects:

- **Edge caching:**

Storing frequently accessed data closer to users at the edge can significantly reduce latency and improve performance.

- **Low latency and high bandwidth:**

These are fundamental requirements for many edge computing applications, enabling real-time responsiveness and efficient data processing.

- **Redundancy and reliability:**

Edge computing systems need to be designed with redundancy and failover mechanisms to ensure high availability and minimize downtime.

- **Scalability:**

Edge computing deployments need to be scalable to accommodate the growing number of edge devices and the increasing volume of data they generate.

By combining these techniques, edge computing can deliver significant benefits, including reduced latency, improved bandwidth utilization, enhanced security, and greater scalability, making it a crucial technology for the future of computing.

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What is Edge Computing?

According to **Gartner**, approximately 10% of data generated by enterprises is processed or produced outside a central data center or cloud—or at the edge of a network. The amount of edge-produced and processed data is predicted to reach 75% by 2025.

This edge computing definition refers to the environments, devices, and processes that happen at the edge of a network.

What Is An Edge?

What is a network edge? The edge of a network refers to where the local network or its devices interact with the internet—the outer border that "touches" the internet. It presents both a **network security** concern and an opportunity to speed up processing closer to—or within—devices at the edge.

Several different classes of devices can operate within an edge computing architecture. Some common edge computing examples include **Internet-of-Things (IoT) devices**. **IoT edge** computing devices can range from toasters to refrigerators to smartwatches to scanners used on a factory floor. There are also **5G networks** that support edge devices, which use the faster processing of 5G to create a smoother end-user experience. These can include any cellphone or wireless device that transmits data over the 5G network.

Edge Computing: Definition & Meaning

Edge computing refers to a distributed information technology (IT) architecture where client data is processed near its source or at the network's edge rather than relying on a central **data center**. This approach enables fast processing, leading to action-led outcomes in real-time compared to the traditional models.

Moreover, edge computing helps businesses improve the use and management of physical assets and create new interactive human experiences. Autonomous robots, self-driving cars, smart equipment data, and automated retail are key use cases of edge computing.

Evolution of Edge Computing

Computing was originally done using one large, centralized computer that often took up an entire room or section of a building. People would either travel from their offices to use the computer or send punch cards with programs to the system's operator, who would input them into the computer.

Soon, users could have their own personal computers, then personal devices, bringing a significant portion of computational processes to, or at least closer to, the edge.

Early days of computing

In the old days, we had one big, central machine that people logged in to in order to take advantage of computational power. Users would connect to this central device and use it to perform tasks and then disconnect.

Advent of personal computing

The advent of the microchip paved the way for personal computers. With personal computers, users could have all the computational power they needed sitting right on top of their desks. There was no longer a need to go to a central computer to perform essential tasks.

Era of cloud computing

With cloud computing, the computational power resides in a data center away from the user—or in "the cloud." We are currently in the cloud computing era. Much of our computing, communications, and even some of the software we use is **cloud native**. With an internet connection, users can interact with these resources without having to over-rely on the computational power of their own devices, which have, as a result, gotten smaller and more convenient.

Edge Computing, IoT, and 5G Possibilities

Edge computing will continue to evolve. Although situation-specific today, edge computing is expected to become more widespread. The growing number of edge-specific appliances and partnerships, like AWS and Verizon, will help improve interoperability and flexibility.

Moreover, wireless technologies like 5G and Wi-Fi 6 will improve edge deployments, creating new possibilities, such as vehicle autonomy and seamless workload migration. The rise of IoT data plays a key role in the growth of edge computing technology. Besides, upcoming innovations, such as micro modular data centers (MMDCs), will bring computing closer to data, enhancing efficiency and scalability. Now that the edge computing meaning is clear, let's understand its types.

How Does Edge Computing Work?

Edge computing involves positioning data storage and computation closer to where it is needed. This results in improved response times and less bandwidth usage, the prime benefits of edge computing. The better response times stem from the shorter distance data has to travel while being used in processes. Instead of going all the way to a central server, as is the case with cloud computing, data can make a relatively short trip to a processor positioned at the edge, such as within a factory.

The reduction in bandwidth that edge architectures experience is a result of less data having to travel over the internet to remote data centers. Instead, it goes back and forth between devices and computational resources closer by, which is one of the primary reasons why we need edge computing.

What Are The Different Types Of Edge Computing?

There are several types of edge computing. Organizations can specify one or more, depending on their computational needs or those of their products. Some are designed to handle basic events, while others are suited for more complex processes. Also, edge computing servers can be used to deploy entire edge computing networks.

Edge computing for basic events

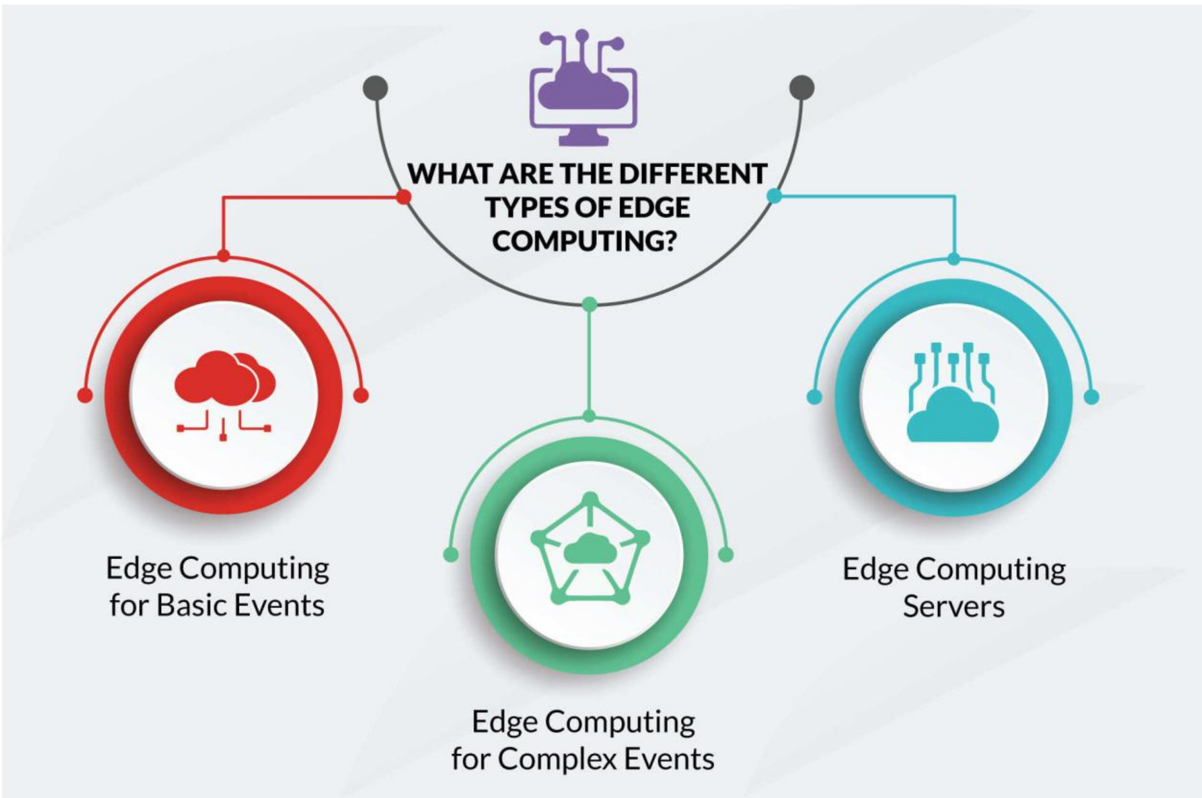
Some of the most simple forms of edge computing involve basic events and straightforward processes. For example, a device that can monitor someone's pulse and blood pressure can be positioned on their body and then send information to an edge-based server. Only certain information is then sent to the cloud, while most of it is handled within the edge network.

Edge computing for complex events

In a more complex edge computing environment, the edge infrastructures can serve as gateways between local data and that coming from outside. For example, with an edge computing setup within a vehicle, the edge computing infrastructure can collect data from Global Positioning System (GPS) devices, traffic signals, and other vehicles to improve the experience of the driver, enhance safety, and optimize fuel efficiency.

Edge computing servers

Edge servers perform many of the functions of full-fledged data centers. They are deployed, for example, in 5G networks and are capable of hosting applications and caching content close to where end-users are doing their computing. With this topology, the data does not have to travel all the way to a remote data center for the edge device to function properly.



Where Is Edge Computing Used?

Edge computing is used in almost every industry now. Because faster processing time and the optimization of data flow improves nearly every organization's infrastructure, many have adopted edge computing environments. Further, IoT devices often use edge computing for their most basic functions, which makes edge computing a compelling environment for any business that uses or sells IoT devices.

Here are some edge computing examples.

Manufacturing

Edge computing aids in the manufacturing process because edge devices can provide information to machines, robots, and users quickly and without using a lot of bandwidth. For example, scanners can be used to check the status of a vehicle being built as it travels along an assembly line. Users can leverage this information to improve processes and make them safer.

Healthcare

Edge computing plays a major role in the healthcare system because much of patient care depends on immediately available information. Edge devices are used to instantly convey data regarding the vital signs of patients, allowing doctors and nurses to make important decisions quickly and with accurate information.

Transportation

The transportation industry benefits greatly from edge computing because of the proliferation of useful information that vehicles and drivers can use to increase safety and enhance the experiences of travelers and drivers. Vehicles with self-driving technology can take input from their surroundings and other vehicles and use them to make decisions. Some of the data they collect and use either comes from or gets sent to the cloud, while other data is processed at the edge.

Farming

The agricultural industry leverages edge computing to enhance the processing of data while reducing bandwidth requirements to improve how crops are grown, taken care of, and harvested. Also, data regarding the health and performance of animals, such as dairy cows, can be processed to better inform production expectations, the care of animals, and the management of energy resources that support the farm.

Telecommunications

Telecoms have been and will likely continue to be one of the most prominent beneficiaries and providers of edge computing. Because telecommunications organizations help companies set up networks, they rely on edge computing topology to enable a wide range of devices to connect to the organization's network and function near its edge. Everything from virtual reality headsets to gaming devices to IoT devices on manufacturing floors interact with edge computing topologies set up by telecoms.

Further, a telecom can set up a distributed cloud that links a series of on-premises servers designed to support complex edge computing setups.

Edge Computing: Benefits & Challenges

Edge computing can enhance the speed at which applications process data, making instantaneous computing convenient for end-users. In some cases, the amount of time saved in an edge computing-based process can make what would be an otherwise unsafe situation safer. In healthcare, edge computing has saved, and will continue to save, lives. Within manufacturing, edge computing improves the efficiency of production while simultaneously creating a safer environment for workers.

Reduce latency

Latency reduction is one of the hallmarks of edge computing, and it is made possible because of the proximity of the edge devices and where their data is stored and processed. When data has to be sent through the internet, it may have to travel hundreds of miles. While many processes can function adequately with the resulting delay, some are so time-sensitive that you need an edge-computing architecture to support them.

Reduce bandwidth requirements

In a more complex edge computing environment, the edge infrastructures can serve as gateways between local data and that coming from outside. For example, with an edge computing setup within a vehicle, the edge computing infrastructure can collect data from Global Positioning System (GPS) devices, traffic signals, and other vehicles to improve the experience of the driver, enhance safety, and optimize fuel efficiency.

Real-time processing applications

Some processes require real-time processing to perform their most basic functions. For example, self-driving cars need to process the information they receive from sensors regarding the speed and proximity of vehicles, people, and various objects. With edge computing, this can be done instantly, enhancing the safety of the driver and others.

Reduced costs

By reducing the amount of information that needs to get transmitted across the internet, an organization may not have to use as much bandwidth. Therefore, they may be able to reduce the amount they spend each month paying their internet service provider (ISP).

Smart applications

A powerful edge device can support smart applications. These can incorporate machine learning and artificial intelligence, taking advantage of their proximity to the source of input. In this way, smart applications can recognize patterns in the environment of the edge devices on which they operate, and then use this information to adjust how they function and the services they provide.

Data privacy

Whenever personal data has to travel to the cloud, it gets exposed to a variety of security threats—either within the database itself or as it gets transmitted to the internet. With edge computing, you can enhance data privacy by limiting the flow of data between the edge device and where it is processed and stored locally.

What Are The Disadvantages Of Edge Computing?

Edge computing comes with a few significant drawbacks as well. Not only can edge devices fail or lose their connection, but without the computational power of cloud-based resources, some applications simply cannot provide adequate performance within an edge topology.

Device failures

If an edge device fails, there is often no redundancy in place to maintain business continuity. The end-user would have to have a backup edge device connected to the same computational and storage services. In many situations, this kind of resiliency plan would be prohibitively expensive.

Limited capability

Many edge devices do not have the power needed to do complex computing. A cellphone, for example, while powerful compared to what was produced decades ago, still pales in comparison to even a mid-range laptop when it comes to power. The capabilities of a data center can further dwarf the potential of the majority of edge devices.

Network connectivity

A dependency on connectivity is an inherent flaw of all edge topologies. The infrastructure that supports many edge devices still has its foundation in cloud data centers. If the connection between the edge device or network and the cloud is lost, the topology may fail to perform altogether.

Further, if an edge device loses its connection to the computational resources that support it, in many cases, it could be rendered useless. This holds true even in edge setups that do not rely on the internet to function.

Edge Computing vs Cloud Computing vs Fog Computing

Let's understand edge computing vs cloud computing vs fog computing.

How Edge Computing Differs From Cloud Computing

Edge computing involves running workloads at the edge, which means closer to devices and end users, while cloud computing refers to running workloads in a cloud provider's data center. However, it's crucial to understand that cloud providers also offer edge computing services.

For instance, AWS provides edge services that enable data processing, analysis, and storage near your endpoints. This allows organizations to deploy APIs and tools outside of AWS data centers.

The Role of Fog Computing

Fog computing temporarily stores and analyzes data in a compute layer between the cloud and the edge when edge devices can't handle processing due to limitations. From the fog, relevant data is then sent to cloud servers for long-term storage and future analysis. Fog computing processes some data locally, which helps reduce the load on cloud servers and improves IT efficiency.

For instance, a building management organization using smart devices to automate temperature control, lighting, ventilation, fire, and security may avoid constantly sending data to the main data center. Instead, each building has a server that handles immediate issues and only sends aggregated data when computing resources and network traffic have extra capacity. This fog computing layer thus helps the company optimize IT performance without compromising efficiency.

However, edge computing doesn't depend on fog computing. However, fog computing is an additional option to help organizations perform efficiently in certain edge scenarios.

How Edge, Cloud, and Fog Computing Work Together

Cloud computing enables organizations to store and process large-scale data on remote servers over the internet. This allows them to offer secure remote access and scale the data. Next, edge computing allows capturing, processing, and analyzing data at the network's edge. This approach reduces the need to communicate with the central data centers. Fog computing temporarily allows processing and storing data between the cloud and the edge when edge computing devices can't manage the load.

This way, edge, cloud, and fog collaboration helps optimize speed, efficiency, and decision-making.

What Are The Security Concerns With Edge Computing?

Edge computing comes with significant security concerns, most of which stem from the novel **attack surfaces** edge topologies create. With a cloud-based topology, even though you have to put up with slower response times, the attack surface beyond the end-user's local network is limited to the data centers that form your cloud. However, with edge computing, every edge device connected to the system is another attack surface.

For example, if you have an edge device within a factory, a worker has to log in to use it. After they log in, they send information to a local server that then also sends data to the device. If the device has a weak password, it would be easy for a hacker, disgruntled worker, or another malicious actor to send harmful code to the server that supports the edge network. Further, it would be relatively easy to spy on the activity within the network, as well as the data that is transferred throughout the network, if proper security measures are not in place for each device.

An edge computing environment is also susceptible to **distributed denial-of-service (DDoS) attacks**, particularly if it is connected to the internet. Because many edge networks are still connected to the internet, a DDoS attack could render the devices on the edge useless. It is vital therefore to ensure your edge network is adequately secured.

Edge Computing Use Cases

Edge computing involves transmitting data quickly using sensors connected to people or equipment. Edge computing architecture enables quick interactions between devices and software, such as in the following applications:

IoT

IoT devices in the mining industry can sense changing conditions far below the surface of the earth. They then send alerts or interact with safety mechanisms to prevent a potentially dangerous situation.

Autonomous vehicles

Autonomous vehicles are among the more popular edge computing use cases, particularly because these vehicles already play a significant role in a variety of industries. For example:

- **Shipping and fulfillment centers:** Autonomous vehicles use data obtained through edge computing to navigate through warehouses, picking up items that need to be sent out—with minimal help from humans.
- **Fleet management:** A fleet of trucks can be guided by a single driver at the front of the pack. Using a communication node, the driver's truck transmits data to the other vehicles. This enables the driver's actions and their vehicle's movements to automatically control the rest.

Predictive maintenance

A current use of edge computing that saves companies both time and labor is predictive maintenance. This form of edge computing technology depends on devices or software that monitor the performance of an asset. If something is on the verge of malfunctioning, data transmitted through the edge computing system can help detect the potential issue ahead of time.

Hospital monitoring

In hospitals, edge computing can be deployed in monitoring devices to gather data regarding a patient's health. This use case fits the typical edge computing definition because it uses nodes to transmit information to the monitoring machines. The time saved can prevent serious health conditions from getting worse.

Secure edge computing environments with real-time network access control and automated threat response. Protect Your Edge Networks with **FortiNAC**

Edge Computing: Redefining Digital Infrastructure and Connectivity

Edge computing enables data processing closer to the network's edge, reducing latency and dependency on central data centers. This approach allows efficient handling of real-time data. With its increasing integration into IoT, 5G, and smart systems, the future of edge computing is promising.

FortiNAC discovers all connected devices in the network, manages their access to resources, and automatically responds to vulnerabilities. As a zero-trust access solution, it protects all digital assets across the enterprise network, covering IT, IoT, OT/ICS, and IoMT devices. With FortiNAC, organizations gain visibility, control, and automated response to network events, thus ensuring robust protection in edge computing environments.