Edge Computing – Types, Applications, and Challenges

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Edge computing refers to a **distributed information technology architecture** wherein data undergoes processing at the network's periphery, positioned as close as feasible to the source of origin. Generally, the data source for edge computing is an Internet of Things (IoT) sensor.

Edge computing enables faster and more extensive data processing with low latency and at less cost than cloud computing, resulting in real-time action-led outcomes.

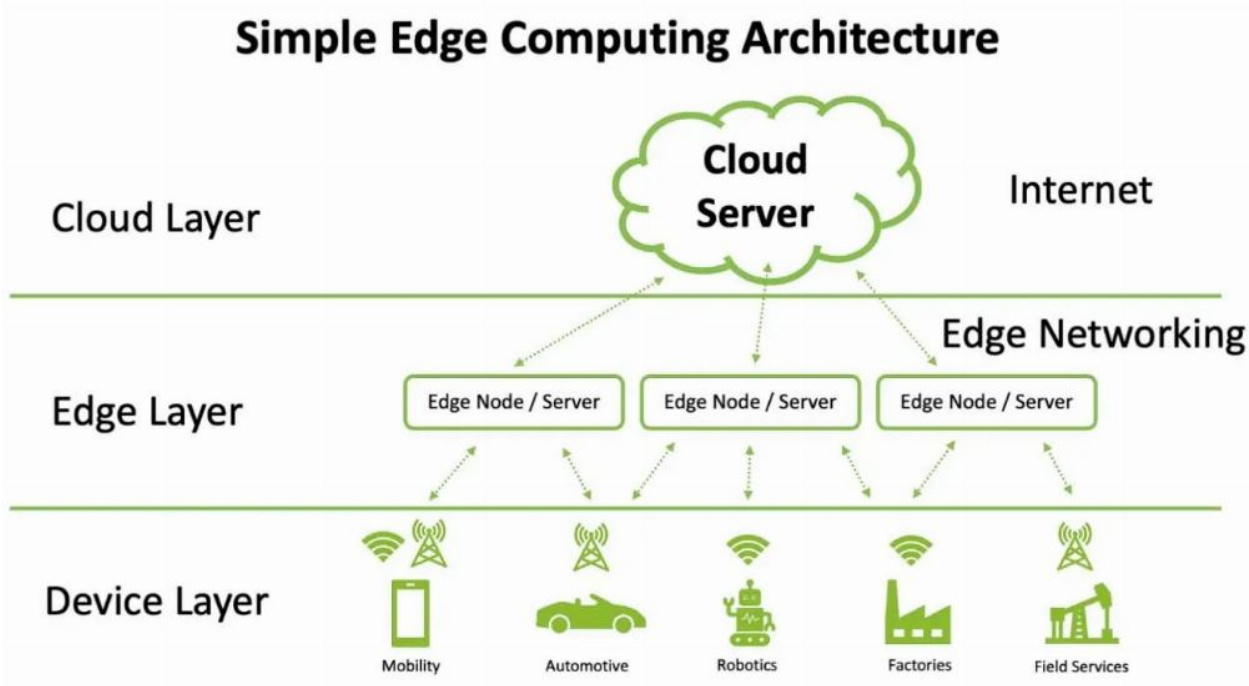
Edge Computing is not a specific technology in itself but an architectural approach to improve the overall performance of computing. Examples of edge use cases include self-driving cars, smart grids, autonomous robots, data from smart equipment, and automated retail.

Evolution of Edge Computing

The origin of edge computing goes back to the 1990s when the first content delivery network (CDN) was created which put data-collecting nodes closer to the end users. However, the technology was limited to videos and images rather than massive workloads of data.

- **Peer-to-peer networks:** In the 2000s, with the the shift to mobile and early smart devices, the strain on existing IT infrastructure was increased which led to the creation of pervasive computing and peer-to-peer overlay networks.
- **Cloud computing:** But, it was the mainstream application of cloud computing when the true decentralization of IT began which provided end-users processing power with increased flexibility, on-demand scalability as well as collaboration from anywhere in the world.
    - Later, as the demand for cloud-based applications working from multiple locations increased, it became necessary to process more data outside of the centralised locations to the source of origin. This made mobile edge computing a reality.
- **Future:** Considering that IoT and edge computing are still in their relative infancy, their maximum potential is yet to be achieved.

How Edge Computing Works?



Edge computing operates by bringing computation and storage closer to both data producers and consumers. The deployment of edge computing varies across different use cases, generally falling into two main categories.

- **Upstream Applications:** In upstream applications, the focus is on collecting data from smart sensors and devices, followed by transmitting it to data centers for further processing.
    - Edge computing strategies in upstream applications involve distinguishing between these types of data sources, transmitting only critical information to the data center.
- **Downstream Applications:** In downstream applications, the priority is on delivering data to end users. Examples include live video streaming, online gaming, or virtual reality video feeds.
    - Edge computing in downstream use cases aims to reduce network latency, ensuring users experience real-time events.

Cloud Vs. Edge Computing

Edge computing should be considered as the next evolution of cloud computing. However, the difference between the two are as follows:

Cloud Computing	Edge Computing
- It is a non-time-sensitive data processing.	- It is real-time data processing with high speed.
- It needs a reliable internet connection.	- It is remotely located and needs limited or no internet connectivity.
- It is useful for dynamic workloads and large datasets, hence it is costly.	- large datasets are too costly to send to the cloud, hence it is cost effective.
- It places data in cloud storage.	- It is useful for highly sensitive data and follows strict data laws.

Hybrid system: Cloud and Edge computing have distinct features and most organisations benefit from using both - **hybrid-cloud architecture**, which allows enterprises to take advantage of the security and manageability of on-premises systems of edge computing while using public cloud resources from the service providers.

Types of Edge Computing

There are four main types of edge computing. Each type refers to a different physical location and exists logically in a different place within a network.

Device Edge Computing	- It refers to various types of devices that perform dedicated functions deployed across the IoT, such as sensors, smart cameras, and healthcare devices, connected to an edge computing platform. - Most suitable for low compute-intensive functions.
On-premise Edge Computing	- It refers to computing resources that reside at the customer's side, including business locations. On-premise deployments benefit by allowing the ability to process data close to its point of origin. - **Example:** Amazon Go stores are based on **Just Walk Out technology**. Customers enter the store, pick out what they want, and walk out, with their Amazon account charged automatically.
Network Edge	- It refers to edge compute locations at sites or points of presence (PoPs) owned by a telecom operator, such as a central office in the mobile network. - It is especially useful in scenarios where there is no fixed premise.

Regional Edge	- It refers to small carrier-neutral data centers or internet exchanges, often located near tier two and tier three cities. - Various customers can dynamically rent servers here to run their workloads, a practice commonly known as co-location.

Benefits of Edge Computing

By decentralising processing capabilities and bringing them closer to users and devices, edge computing systems markedly enhance application performance, diminish bandwidth requirements, and provide quicker real-time insights.

- **Low Latency**: By processing data closer to where it is generated, edge computing reduces the roundtrip time between devices and the cloud. This is crucial for applications such as real-time analytics, the Internet of Things, and industrial processes.
    - **For example**, KaleidEO Space Systems became the first Indian firm to use it for capturing high-resolution images with the help of an orbiting satellite in real-time.
- **Enhanced Computational Capacity**: It helps optimise bandwidth and enables the transmission of large volumes of data for processing, enhancing computational capacity.
- **Privacy and Security:** Edge computing can enhance privacy and security by keeping sensitive data closer to its source, reducing the need to transmit sensitive information such as healthcare or financial data over networks.
- **Scalability**: It allows for distributed computing resources, making it easier to scale processing capabilities by adding more edge devices as needed.
    - This enables flexible computational requirements.
- **Autonomy:** Edge devices possess the capability to make local decisions independently, eliminating the need for constant connectivity to a central server.
    - This autonomy proves beneficial in situations where intermittent or unreliable network connections are prevalent.
- **Edge AI:** Beyond edge computing, most enterprises are going to benefit from edge-AI, that is the fusion of AI and edge computing. The edge AI offers:
    - Intelligence in data processing,
    - Real-time insights,
    - Persistent improvement in accuracy, etc.

Applications of Edge Computing

Edge computing offers numerous applications across various sectors, including industries and business, education and entertainment, and disaster response.

- **Optimisation of industrial process**: Edge computing enables more efficient localized solutions, helping to avoid industrial disasters.

    - **For example**, sending alarms for various critical parameters and initiating shutdown systems through quicker processing and response.
- **Autonomous Vehicles**: Autonomous vehicles need instant decision-making, and relying on a remote server isn't practical. Edge technology allows efficient vehicle communication, enhancing interactions without the need to send data to a remote server first.
- **Disaster management**: It allows for more efficient and rapid insights from satellite data. This capability enables real-time disaster response through cloud detection, road network and building footprint identification, water-body detection, and image template matching for change detection.
    - **Example: SatSure Analytics**, an India-based company, has deployed edge computing in space to meet national security needs, including quick disaster response.
- **Medical Devices and Surgery**: It is crucial to prevent fatal delays caused by transmitting data to the cloud before making decisions.
    - **Example:** Robot-assisted surgery must process data more precisely in real-time, made possible by edge computing, rather than relying on clouds, which could be fatal.
- **Entertainment and educational industries:** It enables the low-latency online streaming of content.
    - **For example**, OTT platforms like Amazon and Netflix, as well as EdTech companies, deliver content by leveraging edge computing.

Challenges of Edge Computing

Though this distributed computing paradigm offers numerous advantages, there are certain challenges that must be addressed to fully harness its potential.

- **Limited 5G Rollout**: The expansion of edge computing in the industry is contingent on 5G, enabling faster real-time data analysis on devices.
    - However, due to the limited rollout of 5G, optimal edge computing functionality cannot be achieved.
- **Security and Privacy**: The distributed nature of edge devices increases the attack surface and potential vulnerabilities, leading to data breaches and critical information leakage.
- **Data Management and Storage**: Managing and storing large volumes of data generated at the edge poses a significant challenge due to the limited storage capacity and computational power of edge devices.
- **Scalability and Resource Constraints**: Scaling edge computing deployments to accommodate growing workloads and user demands is challenging due to the limited processing power, memory, and energy resources of edge devices.
- **Deployment and Management Complexity**: Deploying and managing edge computing infrastructure and devices present complexities, including remote device management, software updates, edge application deployment, and monitoring.
    - Simplifying these processes is crucial for efficient operations.

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