Module III

Edge Computing: Overview, Edge computing terms and definitions, advantages, applications-grid computing: grid layered architecture, Distributed computing, mobile edge computing: introduction, reference architecture, application in 5G technologies.

EDGE COMPUTING

Edge Computing brings the decentralization of networks. Edge Computing is the upcoming enhancement and advancement in technology. The literal meaning of the word 'Edge' is the geographic location on the planet to deliver services in a distributed manner. Edge Computing is a distributed computing system that allows to bring computation of data and storage too close to the source (where data is required). It brings computing as much close as possible so as to minimize the bandwidth, improve response time, and use of latency. Instead of locating the data at a centralized place, the concept of edge computing believes in distributing the computing process of the data.

However, cloud computing and IoT are faster plus efficient, but edge computing is a more faster computing method. The objective of Edge Computing is to improve the network technology by moving the computation of data close to the edge of the network and away from the data centers. Such a process exploits network gateways or smart objects for performing tasks and provide services on behalf of the cloud. As it is well-known that per day data is produced in a huge amount that makes its computation difficult and complicated to be handled by the data centers.

Also, the network bandwidth limit almost gets exhausted, and response time increase highly. So, when moving computation and data services in the hands of edge computing, it is possible to provide efficient service delivery, better data storage, and IoT management that could minimize the response time and transfer rate of data. With the 5G data network, it has enabled to converge 5G data network and edge technologies within reach. Thus, Edge Computing reduces the long-distance processing and slow communication of the data.

ADVANTAGES OF EDGE COMPUTING

1. **Speed:** It is the most attractive and essential factor in any field and especially in the computer science field. Edge Computing will definitely benefit these sectors because of its extremely fast computing speed. Through edge computing, the latency of the networks

will be decreased, and also IoT devices will process data at edge data centers. Thus, data need not be travelled back to the central server (i.e., centralized server).

2. **Security of Data:** In edge computing, data is located near to the source, which will distribute the work of data processing across several data centers as well as devices. It will safeguard your data from any type of cyber-attack that can be vulnerable for confidential data such as safeguarding data from DDoS attacks. Thus, the data can be saved from the hackers to harm the data as the area of attack will increase because data is not placed at a single location only, i.e., data is decentralized.
3. **Scalability of Data:** Scaling becomes easy and simple with edge computing where one can buy edge devices with high computation power for increasing their edge network. There is no such requirement to make their own private and centralized data centers for fulfilling their data needs.
4. **Faster Data Processing:** There are varieties of IoT applications that operate together, and if they are centralized, the server will no doubt slow down the speed. Edge computing data can be accessed locally or near to the connected devices. Through, edge computing the cost of moving data, i.e., (traveling cost) to a centralized server, is also saved, and the time is taken for processing the data also becomes fast.
5. **Cost-Effectiveness:** Edge Computing has gain popularity because it is the most cost-effective method as compared to the existing alternative technologies. It is because edge computing reduces the cost of data storage, network costs, data traveling costs, and data processing costs.

APPLICATIONS OF EDGE COMPUTING

1. **Transportation:** It is one of the most potential sectors where edge computing plays a vital role and particularly in autonomous vehicles. It is because autonomous vehicles are full of different sensors types from the camera to the radar system of the car. Such autonomous devices can essentially utilize edge computing for processing data too close to the vehicle through these sensors, and consequently, a good amount of time will be saved.
2. **HealthCare:** People rely on fitness trackers, smartwatches, stamina measurement watches, etc., and find these health-monitoring wearable comfortable. However, the real-time analysis is essential for capturing the actual benefits of the collected data because many health wearables devices are directly connected to the cloud while others can be operated in an offline mode only.

3. **Manufacturing:** Edge computing in the field of manufacturing will reduce the data that goes to the cloud for applications like predictive maintenance, and it will move the operational technology to the edge computing platforms for running process similarly as processed in the cloud but with more speed and result.
4. **Grid Edge Control and Analytics:** These smart grid controls work by creating two-way communication channels via WAN protocols between the power distribution infrastructure, consumers, and the utility head-end. However, edge grid computing is capable of providing advanced real-time monitoring and analytics and also producing actionable insights on distributed energy that generates resources like renewables. Such capability is available in edge computing technologies only.
5. **Remote monitoring of Oil and Gas:** At present, IoT devices are providing modern safety monitoring, sensory devices for controlling, viewing, and sensing the temperature, pressure, moisture, humidity, sound, and radiation of oil and gas. IP cameras and other IoT devices generate massive and continuous amounts of data, and then the data is combined as well as analyzed in order to provide the key insights for evaluating the health of any running system reliably. With edge computing, real-time safety monitoring can be possible for safeguarding critical machinery infrastructure and oil and gas systems from disasters. Edge Computing allows analyzing, processing, and delivery of data to the end-users in real-time.
6. **Traffic Management:** Traffic is the worst waste of time and needs to be optimized. The best way to optimize traffic is by maintaining and improving real-time data. For the traffic management process, the smart transportation systems such as self-driving cars, and other sensory systems make extensive use of edge computing devices. Through edge computing, a massive amount of sensory and other data is analyzed, then filtered, and finally compressed before transmitting on the IoT edge gateways to other systems for use. As a result, edge computing reduces network expenses, operating processing, and storage cost for undertaking traffic management solutions.

GRID COMPUTING

The use of a widely dispersed system strategy to accomplish a common objective is called grid computing. A computational grid can be conceived as a decentralized network of interrelated files and non-interactive activities. Grid computing differs from traditional powerful computational platforms like cluster computing in that each unit is dedicated to a certain function or activity.

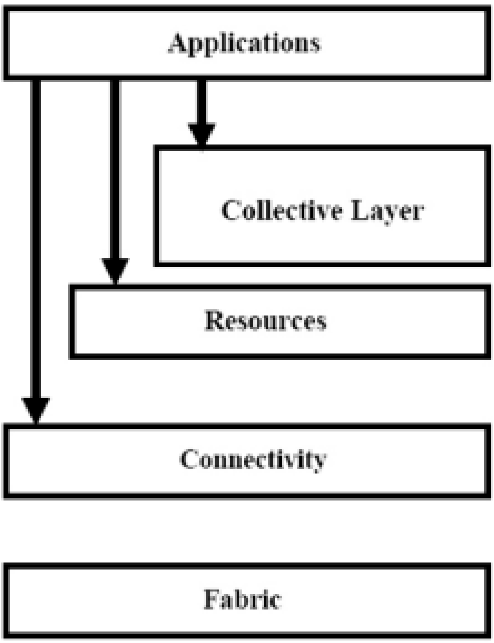
Grid computers are also more diverse and spatially scattered than cluster machines and are not physically connected. However, a particular grid might be allocated to a unified platform, and grids are frequently utilized for various purposes. General-purpose grid network application packages are frequently used to create grids. The size of the grid might be extremely enormous.

Grids are decentralized network computing in which a "super virtual computer" is made up of several loosely coupled devices that work together to accomplish massive operations. Distributed or grid computing is a sort of parallel processing that uses entire devices (with onboard CPUs, storage, power supply, network connectivity, and so on) linked to a network connection (private or public) via a traditional network connection, like Ethernet, for specific applications. This technique has been used in corporate entities for these applications ranging from drug development, market analysis, seismic activity, and backend data management in the assistance of e-commerce and online services.

Grid computing brings together machines from numerous organizational sectors to achieve a similar aim, such as completing a single work and then vanishes just as rapidly. Grids can be narrowed to a group of computer terminals within a firm, such as accessible alliances involving multiple organizations and systems.

GRID LAYERED ARCHITECTURE

Grid architecture has a 5-layer basis. The layers are:

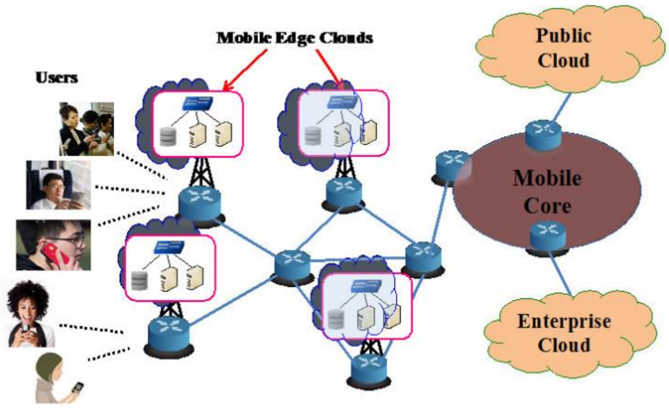


1. **Fabric Layer:** The lowest layer in grid architecture. All shareable resources are placed in this layer; such as processors, memories, sensors and actuators. It is clear that in grid network, grid protocols are responsible for resource control.
2. **Connectivity Layer:** In this layer those protocols are placed which are related to communication and authentication.
3. **Resource Layer:** All common actions related to network parts are guided in this layer; like negotiation, initiation, monitoring, control, accounting and payment.
4. **Resource Layer:** All common actions related to network parts are guided in this layer; like negotiation, initiation, monitoring, control, accounting and payment.
5. **Collective Layer:** Any Collaborative operations in the shareable resources are placed in this layer.

MOBILE EDGE COMPUTING

Relevance of cloud computing to mobile networks is on an upward spiral. Social network services like Facebook and Twitter, the content from YouTube and Netflix, and navigation tools from Google Maps are all on clouds. Besides, users' increasing reliance on mobile devices to carry out compute and storage intensive operations, whether personal or business related, require offloading to the clouds for achieving better performance extending battery life.

These objectives would be difficult and expensive to realize without bringing the cloud closer to the edge of the network and to the users. In response to this requirement the mobile operators are working on Mobile Edge Computing (MEC) in which the computing, storage and networking resources are integrated with the base station. Compute intensive and latency sensitive applications like augmented reality and image processing can be hosted at the edge of the network. Fig. 1 shows this concept.



MULTI-EDGE COMPUTING REFERENCE ARCHITECTURE

The IoT devices, the Edge devices and the cloud are organized in a hierarchy. The IoT devices form the lower layer, the MEC devices form the middle layer and the cloud forms the upper layer. MEC is arranged into two levels (the Mobile Edge system level and the Mobile Edge host level). Each of the levels is composed of components that communicate with each other using reference points.

The Mobile Edge system level

This level consists of five (5) components:

1. Customer Facing Services (CFS) portal
2. Operational support system (OSS)
3. Mobile Edge (ME) orchestrator
4. User App LCM proxy
5. User Equipment App

(a) The CFS portal

The CFS portal is an entry point for third parties. Third parties include developers, enterprises and business clients. Developers may use this component to make applications available in the mobile operator, whereas enterprise may use the same portal to select applications of interest to them and give instructions of use of some selected applications.

In addition, this portal is used to relay business related information which may include what services are available, billing, and service level agreements. Moreover, this portal is used by operations to manage provisioning, and other related services of the ME application. The CFS portal communicates to operations support system through reference point Mx1.

(b) User Equipment Application (UE app)

User Equipment Application is an entity of MEC architecture at the mobile system level, UE app defines applications in the User Equipment that have the capability to interact with the mobile edge system via a user application management proxy. The user application is a mobile edge application that is instantiated in the mobile edge system in response to a request of a user via an application running in the UE. UE connects to the user application lifecycle management proxy through reference point Mx2.

Mx2 is used by a UE app to request the mobile edge system to run an application in the mobile edge system, or to move an application in or out of the mobile edge system. This reference point is only accessible within the mobile network. It is only available when supported by the mobile edge system.

(c) The Operations Support System (OSS)

OSS is the highest management system entity of the MEC architecture that promote mobile system to run in a desired location on a network. OSS receives instructions to instantiate or terminate mobile services from both CFS portal and user equipment. Moreover, it acts as a bridge between the operator and external world, checks integrity and authenticity of application packages. It also authorizes and forwards request to ME orchestrator for further processing.

The OSS receives requests via the CFS portal and from UE app using reference points Mx1 and Mm8 respectively. Reference Mx1 is used by the third-parties to request the mobile edge system to run applications in the mobile edge system and Mm8 is used to handle UE applications requests for running applications in the mobile edge system. OSS may have capacity to relocate applications between servers.

(d) User Application Lifecycle Management (LCM) proxy

User Application Lifecycle Management (LCM) proxy is an entity that allows UE applications to request on-boarding, instantiation, termination of user applications and when supported, relocation of user applications in and out of the mobile edge system. It also contains information about the state of the user applications.

The user application life cycle management proxy authorizes requests from UE applications in the UE and interacts with the OSS and the mobile edge orchestrator for further processing of these requests. The user application life cycle management proxy is only accessible from within the mobile network; besides it is only available when supported by the mobile edge system.

(e) Mobile Edge Orchestrator (MEO)

MEO is an entity in the mobile system level which maintains an overall view of the mobile edge system based on deployed mobile edge hosts, available resources, available mobile edge services, and topology.

It is responsible for on-boarding of application packages, checking the integrity and authenticity of the packages, and validating application rules. It may adjust requirements to comply with operator policies, and keeping a record of on-boarded packages. In addition, it prepares the virtualization infrastructure manager(s) to handle the applications. The MEO is tasked with the selection of appropriate mobile edge host(s) for application instantiation based on constraints, such as latency, available resources, and available services.

Further, it triggers application instantiation and termination, application relocation as needed when supported. Reference point Mm1 connects the orchestrator to operation support system and Mm9 connects the orchestrator with user application life cycle management (LCM) proxy. Mm1 is used for triggering the instantiation and the termination of mobile edge applications in the mobile edge systems, whereas Mm9 is used to manage mobile edge applications requested by User Equipment app.