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Future of Cloud Computing: Fog, Edge, Mist, Dew and its' Comparative Study and Challenges

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ABSTRACT

Real time application requires latency-aware computation. Today's emerging technology is IoT. This environment generates vast amount data named as Big data. To handle this Big data, the Cloud computing concept is introduced. It is based on internet-based computing. As there is increase in failure of Data centers, problems are increased drastically. To overcome this issue Fog concept is introduced. Fog computing resides closer to the IoT devices. It extends cloud-based computing, storage and networking facilities. These Fog nodes can be distributed anywhere with network connection. It should support all kind of time sensitive application. Mist computing is an emerging technology. Mist network is located at IoT objects. Functionality and timings are dynamic and adjustable. It follows high level application specific rules. New applications can be assembled from existing devices at runtime. Hence more services are pushed from Cloud to the Edge as it requires less response time and better reliability. Cloud computing, Fog computing and Edge computing heavily rely on internet. To overcome this problem Dew computing paradigm is used. Dew server holds control and flexibility toaccess data in absence of internet connection. Dew computing concentrates on information processing and high productivity. It is the future direction of on- premises computer application. There is need to further exploration. This paper emphasizes on current trends, its' comparative study and challenges of Cloud computing related terms.

KEYWORDS: IoT, Data Centers, Cloud, Cloudlet, Fog, Edge, Mist, Dew Computing categories, On- premises computer, Cloud-Dew Architecture.

1. FUTURE OF CLOUD COMPUTING:FOG, EDGE, MIST AND DEW

Real time application requires latency-aware computation e.g. An emerging technology the 'IoT' i.e. Internet of Things (IoT). The huge amount of data is generated known as Big data. In a cloud infrastructure, on-demand services help to process data. For some application, it is not efficient solution as it takes too much time. Fog computing is the best solution for it. The IoT is ready to apply major stresses to the current internet and data center infrastructure.

Different terms:

2. DATA CENTER

It facilitates data storage and access A part of on-premise IT infrastructure.

a. *Storage Data Center:* It refers to the devises, equipment and software technologies. It enables data and application storage within data center.

b. *Internet Data Center*: Business rent out server from data centers to store online files. It saves location for files accessible from the internet.

3. CLOUD

It is a kind of internet-based computing. It is aggregation of servers. We can access program and data via internet anywhere from world. It is an off-premise resource for data storage. It is accessed over network. The main drawback of cloud computing is that it always needs internet connection. Cloud computing model means to have all software and data on server or group of servers that you can access through the internet. User can access services on the cloud without knowledge of

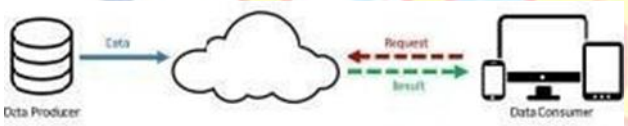

Fig.1 Cloud Computing Paradigm [5]

managing the resources. The computation of IoT devices depends on cloud, as they are directly connected to the cloud.

a. Private Cloud: The immaculate private cloud is assembled for on client for client or his private utilization. It is protected and works for a particular association. SaaS, PaaS, IaaS are the most common services provided by cloud. All these services are heading towards XaaS.

b. Public Cloud: It is open to the general population.

c. Community Cloud: It is shared by number of organizations as per their interest and needs. It decreases capital expenditure costs.

d. Hybrid Cloud: It includes various billows of different types. Mist has capacity through their interfaces to exchange from one cloud to another cloud.

4. CLOUDLET (DATA CENTER IN A BOX)

It was introduced in2009. It is a project from research group in Carnegie Mellon University. By introducing multitier hierarchical structure to combine the mobile computing and cloud computing is the main goal of it. It brings location closer to the users and IoT devices. Cloudlet sits between the cloud and the device. It can process data more quickly due to its' proximity to the device [2].

5. FOG COMPUTING

It is virtualized intermediate layer between IoT devices and cloud. Fog and IoT devices are connected to each other. Fog devices are near to users. There is big challenge of resource allocation and task scheduling while running any IoT application in a Fog a environment. Fig.2 represents a model of Fog Computing.

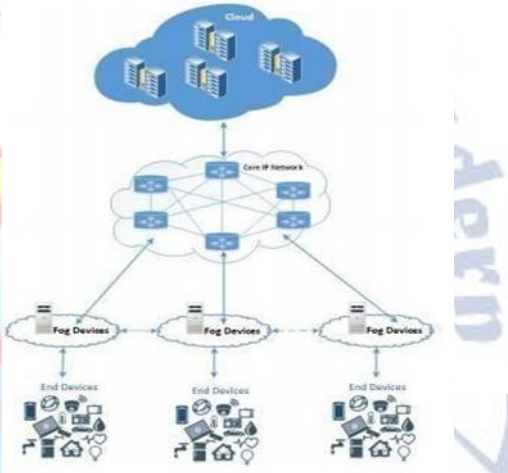

Fig. 2 A model of Fog Computing [2]

Computationally capable, networking and storage capacity of any device act as a Fog device. The device which works in Fog premises is referred to as Fog device from technical point of view. Fog devices are present in between cloud and IoT. In a specific domain, Fog devices are controlled by Fog server. Fog computing pushes only related data to the cloud. It facilitates computing, decision making and action taking through IoT devices. It focuses more on infrastructure side. Fog can replace cloud or Fog is better than cloud is not true. Both contributes in different ways [2]. Local Analysis of sensitive data instead of sending it to the cloud. It conserves network bandwidth. Independent Fog devices consult directly with the cloud. Independent Fog devices may consult with each other.

Cisco Global Cloud Index signifies that data generated by human being, machine, and IoT devices will reach 500 zettabytes by 2019. By 2020, more than50 billion things

will get connected to internet. Inupcoming era, to handle this enormous data only cloud computing is not efficient. To increase the efficiency of cloud computing "Edge Computing" concept came into existence.

6. Edge Computing

It is emerged around 2000. It is defined as processing the data at the edge of the network and then send processed data to the cloud.It is very close to the end devices or source which results in short response time. It reduces the pressure on the network hence increases the efficiency.

The best application of Edge Computing is online shopping service. Here customer frequentlyupdates his/her shopping cart according to the choice. Required changes have to be done by the cloud and updated items should be on shopping cart. This updation process takes lot of time which depends on load on the server and speed of the network. It results in bad experience of the user. If the updation process of the shopping cart is done at Edge and then send it to the cloud server, it will reduce the response time drastically which introduces the term "Edge Computing" [6].

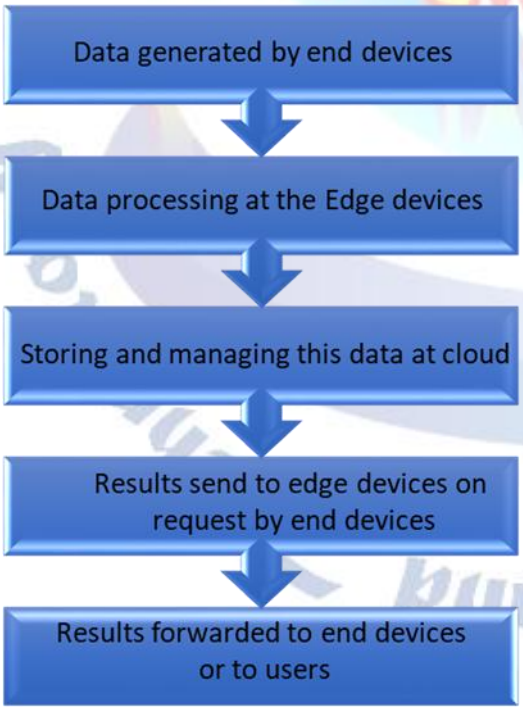

Fig.3 A Data Flow Diagram of Edge Computing

7. Mist Computing

Near the Edge of the IoT architecture, a novel idea is 'Mist computing'. While computing complex application it enhances inherent efficiency. This concept is known as "Mist Computing". While data transmits, it does not thrust control responsibility to gateway. This control is decentralized to end nodes. It increases throughput and decreases communication delay. To build the large scale IoT, Mist computing is useful. Need of user, global situation and physical environment these parameters must be known to Cloud and Fog to execute an IoT application. Communication to the edge devices is required to achieve the global situation. How to behave in particular situation and what to do? must be recognized by Edge device. Routing protocolswhich are wireless are not suitable. Routing protocol supports device to device connectivity. Any particular node should be able to connect to any other gateway. While the failure of the gateway, the nodes near to it must have the ability of dynamic connectivity to the new node and it must establish the connection between those nodes. Mist and Fog are complementary to each other. In gateway, more computationally intensive task can be executed and at the end of the devices computationally less intensive task can be executed [7].

8. Dew Computing

This concept was proposed in 2015.

Definition (Dew Computing): In cloud computing environment this is the computer software-hardware organization, where it provides functions as an independent of cloud services. It also works in collaborative fashion with cloud services. To recognize the strength of servers and cloud services is the main aim of dew computing. It emphasizes on two key features:

1. **Independence:** It means the servers are able to provide such functionality without cloud services and an Internet connection.
2. **Collaboration:** It means the dew computing application has to automatically exchange information with cloud services during its operation [8].

If internet connection is lost, user cannot access his/her own data on cloud. All resources are far from user. To overcome this problem Cloud-dew architecture is provided. Dew servers make avail installed websites

always accessible to users. They synchronize with cloud servers when possible.

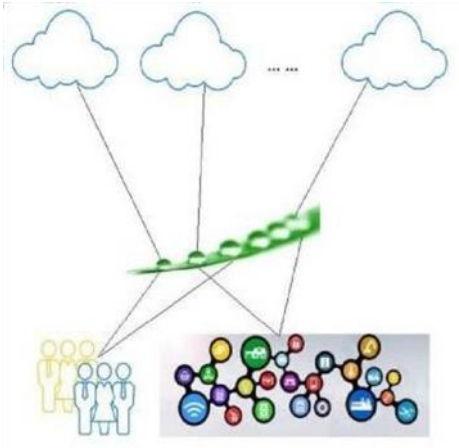

Fig.4 The Structure of Dew Computing [8]

Personal computer termed as "On-premises" computer in Cloud computing. It includes personal computer, tablets, cell phones, servers etc. Non-cloud services and on-premises resources are equivalent in nature. Connection between cloud and dew computing is shown by servers. It was defined as a software organization paradigm. Local computer and its' applications are not necessary to be powerful. e.g. Simple app on cell phone. It is not much powerful but still dew computing applications works on it. When cloud service is not available, this cell phone is able to provide schedule service.

In Fig.4, On-premises computers are represented by green leaf. Running application inside the on-premises computer are denoted by the dew drops on the leaf. Except clod services, other services and devices are features of applications. They also collaborate with cloud services.

Dew computing and its' categories are extremely useful in inspiring new attractive applications.

2. COMPARATIVE STUDY

In the IoT environment huge amount of data is generated known as Big data, which is stored on cloud. As data centres failure increases rapidly, Fog concept is introduced. Due to huge data present on cloud, its services are pushed to Edge. Edge computing requires less response time and better reliability. Mist network is located at IoT object. Its functionality and timings are dynamic and adjustable. All Cloud, Fog, Edge depends on internet. To overcome this problem, Dew computing is introduced. In absence of internet connection, Dew server holds control and provide flexibility to access the data. Comparative analysis of all these terms are shown in following tables.

I.Comparison of Conventional Cloud Computing andEdge Cloud and Edge Computing

Sr. No.	Conventional Cloud Computing	Edge Cloud and Edge Computing
1.	Small number of large sized Data centers	A large number of small sized Data centers
2.	Proximity of services and resources in remote Data centers. Data processing location is farfrom users	Dataprocessing location is at the edge close to the Users
3.	High Bandwidth	Low Bandwidth
4.	High latency	Low latency due to proximity to the user
5.	High risk due to long distance transmission	Lower risk

Table I compares between conventional cloud computing and Edge computing. It compares the terms like size of the Data center, data processing location, bandwidth, latency time and risk factors.

II.Comparison of Cloud Computing and Fog Computing

Sr.No.	Cloud Computing	Fog Computing
1.	Centralized Computing Concept	a. Decentralized Computing Concept b. The devices in fog environment are heterogeneous, ubiquitous. c. It is a standard created by CISCO systems

2.	Energy consumption and operation cost is high	Energy consumption and operation cost is Low
3.	There is multi hop distance between users and Cloud	There is one or two hops distance between usersand Fog
4.	Cloud has huge storage capacity and maximum processing capability.	a. Fog nodes have medium storage and processing capability and end nodes are battery powered. b. Limited memory process and energy resources

Table II Differentiates the terms like energy consumption, operation cost, distance between user and cloud, distance between user and fog, storage capacity, real time interaction, congestion and security.

III. Comparison of Edge Computing and Fog Computing

Sr. No.	Edge Computing	Fog Computing
1.	It take along processing closer to the data source. No necessity to send to remote cloud or centralized sources	It facilitates the operation of computer Storage and networking services between end device and cloud computing data centers
2.	The movement of computation is far away from the cloud provider and it is closer to where the data is being created	Fog computing is bigger than Edge computing.
3.	Devices in the field are gateways, sensors, smartphone, computer etc.	Fog servers, gateways, fog devices are basic computational components.
4.	Edge is part of Fog	Fog starts at the 'thing' (from IoT) and moves up to the Cloud. Fog extends the cloud.
5.	The speed and performance of data transport, devices and applications on the Edge can be improved	It handles process and storage tasks very near to the user.
6.	It focus more on "things" side	It focus more on "infrastructure" side

Table III Considers the factors like movement of computation, devices used in the field, speed and performance for comparison.

9. Related Work

1. Preeti Gupta (2014) explains that, Cloud computing is growing technology in IT. On demand, pay-per-use and rapid elasticity these characteristics are elaborated. Different types of cloud computing i.e. private cloud, public cloud, community cloud and hybrid cloud are differentiated. XaaS taxonomy is defined where 'X' can be software, platform or infrastructure. Well known models of the cloud computing i.e. IaaS, PaaS, SaaS, deployment models are explained. When cloud fails, there is cascading effect upon all which depends on it. The uptime of cloud computing in business running their own infrastructure and downtime in vendor- driven monoculture are introduced. Increasing carbon footprint due to exponential growth of data centres, its' environmental impact is explained. How to overcome this problem is also discussed.
2. Ranesh Kumar Naha(2018) explores the Fog Computing, its Architectures, its requirements.Fog computing was proposed in 2012 by CISCO systems. Overview of fog computing along with its' definition is mentioned. It enables latency-aware smart home services in more efficient way. Research in this area is

rapidly increasing. Dissimilarity between fog and cloud is elaborated. Mobile cloud computing, mobile edge computing, edge computing, dew computing, fog-dew computing concepts are explained in depth. Fog computing architecture is diagrammatically shown. Different components of fog computing are represented with the help of diagram. In simplest way organization of fog computing based on requirement of platform, infrastructure application is shown. Different fog, gateway processing devices (Intel Edison, Raspberry Pi, Tessel 2 etc.) are mentioned. Requirement of platform for fog computing i.e. resource allocation and scheduling, service requirement is explained. The concept of fault tolerance, QoS is described. Security and privacy related issues are discussed. How multi- tenancy is important in fog environment is explained. It may create performance degradation problem and security issues. Dimension of fog computing-based applications are described. Existing work on fog application is evaluated. For simulation 'iFogSim' is the first toolkit. 'CloudSim' is another toolkit that enables simulation and modelling of application provisioning in Cloud computing. Infrastructure, platform and application related issues are discussed. The ideas of fog computing are presented very effectively.

3. Yugandhara A. Thakare (2017) in this review paper introduction to IoT, fog computing is presented. Why there is need of Fog computing for IoT is discussed. As there are many challenges in front of us, to deal with it, fog computing is the best solution. It pushes only related data to the cloud. Fog devices are called as fog nodes, which can deploy anywhere with a network connection. Benefits of fog computing i.e. minimizes latency, conserves network, bandwidth, deal with security are mentioned. It focuses on "Fog computing and Cloud computing both works together. Fog computing can not replace Cloud computing". It optimizes the use of available resources. It addresses challenges of real time process and action of incoming data. This paper gives brief idea about Cloud computing, Fog computing and IoT.
4. Sandeep Kaur (2017) pays attention to the limitations of cloud computing. How to overcome those limitations introduces the term 'Fog computing'. But there are some advantages and disadvantages of Fog computing is also elaborated. This paper gives overall idea of Fog computing in brief.
5. Weisong Shi (2016) attempts to contribute the concept of edge computing. Why do we need it? What is edge computing? How it is beneficial? These questions are answered in simple way. Illustrating our vision towards edge computing, several case studies are mentioned e.g. cloud offloading, video analytics, smart home, smart city, collaborative edge etc. It summarizes different challenges in detail and brings out solution for it. It concludes with the fact that more and more services are pushed from cloud to edge because edge computing takes short response time and better reliability. It saves bandwidth.
6. Saksham Mittal (2017) author explores the term edge computing. Edge computing has resolved several issues and challenges in cloud computing. It defines edge computing concept with the help of data flow diagram.

   Recent trends for Edge computing paradigm and Conventional model of cloud computing is diagrammatically explained. Different applications are also elaborated like image and video Analysis, smart home, smart city, cloud offloading etc. Edge computing resolves issues occurs in cloud computing. Opportunities in edge computing are also mentioned.
7. Manas Kumar Yogi (2017) gives idea about Mist computing. It is a novel idea of computation near the edge of IoT architecture. While computing complex application it improves the efficiency. In data transmission control responsibility is not thrusted to gateway. Control is decentralized to end node. It decreases communication delay by increasing throughput. The basic aim of mist computing is to find out immediate solution to the very edge of the network.i.e sensors, actuators. It should follow the principle i.e. network should deliver only requested information, when it has been requested. Routing and current architecture of mist computing is elaborated. Thinnect company has successfully implemented mist computing. Mist and fog are complementary to each other.
8. Yingwei Wang (2016) explains about a new technology Dew Computing. Emerging trend, Dew computing has countless potential in various application areas. Dew servers keep always installed websites available to user. It synchronizes with cloud

server whenever possible. 'Dew' is the metrological terminology associated with computing. Cloud-Dew architecture is the initial point. Dew computing is defined. Independence and collaboration are the two key features of it. The structure of Dew computing is shown with the help of diagram. Different categories of Dew computing are explained in detail. The goal of Dew computing is pointed out by new definitions. It realizes the strength of servers and cloud services. This paper clears the idea of Dew computing and inspires new application.

CHALLENGES

1. To bring connectivity to every home, vehicle with smart internet connected devices.
2. Various techniques need to be used to overcome data center's failure problem
3. "secondary sleep mode high end servers" and "secondary data links" should be used
4. Expand the Fog computing paradigm in smart grid
5. Include incorporating Fog with Emerging Technology e.g. 5G technology
6. Achievement of success of fog computing depends on fog devices of organization or people.
7. There is existing research work and gaps in scheduling, resource allocation, fault tolerance, simulation tools and Fog based services.
8. There is necessity of extensive investigation for these emerging technologies.

10. CONCLUSION

The Cloud is far away from our computer that is "up in the sky". Fog is "hovering above the ground" very close to the IoT devices. Mist is just below the Fog and Dew is on the ground is part of our Personal computer. Similar to this sequence new inventions are found. To improve the efficiency of the network Big data, Cloud Computing, Cloudlets, Fog Computing, Edge Computing, Mist Computing, Dew Computing technologies are implemented. Improving IoT based applications effectively and efficiently is a big challenge. There is need to be fill up the gap among current research works and resource allocation, scheduling, fault tolerance, simulation tools and Fog based services.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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