# Studying Cloud Vs Fog Computing and its Application

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**Abstract -** *The exponential broadening of the Internet of Things (IoT) constitutes many tough conditions for the conventional paradigm of centralized cloud computing, such as immoderate latency, restricted capacity, and network outages. Cloud computing and Fog computing convey the cloud nearer to IoT computers to defeat these issues. They come up with providing local IoT processing and storage of IoT elements in place of sending them to the cloud. Cloud and Fog bring forth feedback at quicker speeds and better overall performance as compared to the cloud. More secure path of action to make certain that the IoT offers sturdy and dependable assets for multiple IoT customer. The paper presents cloud and fog layout in addition to new IoT technologies, maximum advantageously via the usage of the cloud and fog model and also applications of fog computing.*

***Key Words***: Cloud computing, Fog computing

## 1. INTRODUCTION

In the following period sector, cloud storage is probably developing increasingly. In addition, the cloud framework can be easily configured for accurate activity analysis and time orchestrates for IT run, from storage and duration to database and abilities. The modern cloud infrastructure platform promises to fulfill IT requirements more positively [1]. Various groups are using cloud computing to compile and interpret large amounts of statistical data.

In addition, cloud facilities vendors began to combine systems for related data management in their bundles to help customers access the cloud services [2]. The Cloud infrastructure provides the appropriate access to networks, fast and expedient computer assets.

Fog computation is a distributed computing paradigm that expands the conventional computing cloud capabilities at the grid [3].

Fog computing offers manuscript computing, storing, networking, and application services in an exceptionally visually oriented platform at the edge of end devices and cloud computing data centers [4]. Virtualization is a simple technique for fog computation in isolation.

Physical infrastructure for establishing independent dedicated services to run multiple operating systems and programs on a single resource simultaneously [5]. The fog model is an extension of the cloud.

Cisco's description of the meaning of "fog" was first described to explain the need for a network to meet the requirements of the essential Internet of Things (IoT) services [6]. Fog computing has a virtual architecture targeted at globally distributed services and Software [7-9]. Fog Computing minimizes time for requests to applications provided and delivers local computing facilities for terminal devices and network access to centralized networks where required [10].

The utilization of Fog computing will extend community reliability and enhance the safety of the community. It can dramatically increase bandwidth and energy usage by sending vast data from numerous devices to cloud storage or centralized networking facilities [12, 13]. Today the Internet of Things is attached to every one-of-a-type via some specific agency, business, or basis such as universities. Therewithal, individual people have often related to others via or profitable Internet communications.

The IoT consists of physical artifacts ("objects"), which allow communications components, sensors, software, and electronics to capture and share data [14]. The prevalence of IoT technologies and the expanded digitation of our culture, of which the sharing of knowledge over the Internet has been regularly made up of millions to millions of mobile devices (for example, in smart houses, smart towns, imaginative metering schemes, intelligent vehicles, and large size wireless sensor networks) [7, 15].

This paper discussed cloud and Fog computing and brought IoT abilities extended via cloud and fog. This paper aimed to discuss cloud and Fog computing and IoT and its implementations in our environment, in addition to provide a purpose at the back of practicable avenues for research and open subjects regarding cloud computing and Fog computing integration with IoT

## 2. BACKGROUND CONCEPTS

### 2.1 Cloud Computing

Cloud computing is that the delivery of various services through the web, including data storage, servers, databases, networking, and software. A paradigm that allows the network to enter a shared computer pool with comfortable demand [16] Cloud storage technology offers consumers a way of saving, retrieving, or storing information from an online store [17]. This is possible using cluster software, network infrastructure, distributed file systems, and many more [19]. Cloud computing takes all the work involved in clusters far from the device you carry around or sit and work on. It in addition moves all of that data to terribly massive computer clusters faraway in network. Preferably keeping files on a proprietary disk drive or local memory device, cloud-based storage makes it possible to save lots of them to a foreign database. By implementing parallel computation, cloud computing falls in as a remedy [20]. Parallel computing helps a remote processor systematically transform functions into subroutines [21]. While cloud infrastructure has major strengths over conventional structures, it still has some threats [22].

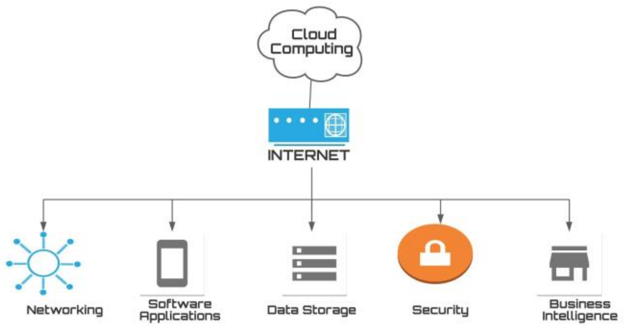


**Fig 1**: Cloud Computing

## 2.2 Fog Computing

Fog computing is an extended cloud computing model from the heart to the network's edge is a term launched by CISCO in 2012 [11]. It permits for computation close to IoT and/or the end-user computers at the sting of the network, wherever virtualization is additionally supported. However, not like the cloud, Fog is associated with the presence of the planet. The relations between the Fog and the cloud were given special attention [18]. Fog computing is characterized as a horizontal system-level architecture that distributes the user's Cloud to Thing functions employing computing, storing, controlling, and networking functions [23].

Fog computing is seen as a necessity for IoT however additionally for 5G, embedded AI (AI) and 'advanced distributed and connected systems. Besides, it is wonderful to handle performance and section problems because of its specific services and resources square measure virtualized wherever it is set at the network's edge. Fog networking enhances -- does not replace -- cloud computing; fogging allows short analytics at the edge, whereas the cloud performs resource-intensive, longer-term analytics. Cloud and Fog complement each other to form an interdependent service continuum and mutually beneficial between the endpoints and cloud to make storage, control, computing, and communication available anywhere along the continuum [24].

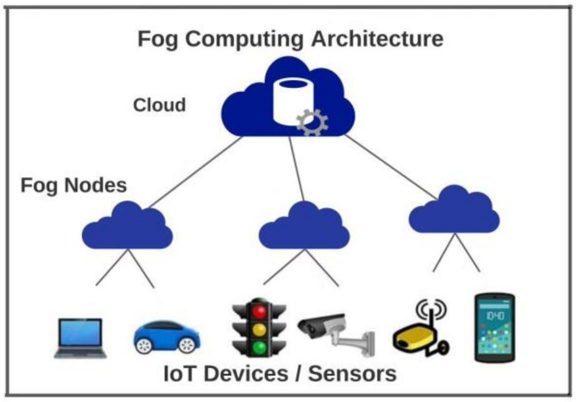


**Fig 2**: Fog Computing Architecture

## 2.3 The architecture of cloud-fog computing-

This model of cloud computing uses the essential 3-layer structure throughout a stratified model, 3 layers include:

1. Terminal layer:

The terminal layer is that the elementary layer among the fog model that contains devices like cell phones, cameras, good cars, readers, smart cards, then on the sensors. Throughout this layer, the information is discovered and collected. Devices are distributed and removed widely from one another over a variety of locations.
The layer deals additional with sensing and gathering of information. Devices from varied platforms and diverse architectures are essentially found. Applications will run in a very heterogeneous setting with completely different devices with different technologies and utterly different communication modes.

2) Fog Layer

The Fog layer contains instrumentation remarked as Fog nodes, like routers, gateways, entry points, base stations, individual fog servers, then on.
The fog nodes unit placed at the sting of a network. A edge is in addition a hop removed from the end of the unit. These nodes unit of measurement set between Cloud Data Centers and End Devices.
Fog nodes are static, like those in canteens, or they are mobile, like those among an automobile.
These nodes provide the right devices with facilities. It also can shortly estimate, transmit and store the information.

3) Cloud Layer

This layer consists of computers, which will offer high performance with immense storage and machines (servers). The cloud layer conducts the study of computations, saves data for backup, and remains consistent user management.

It has excessive capabilities for storage and structured computation.
A cloud layer is designed by huge data centers with high technical ability. The data centers offer customers with all the essential functionalities of cloud computing. The data centers are versatile and have on-demand computing services.

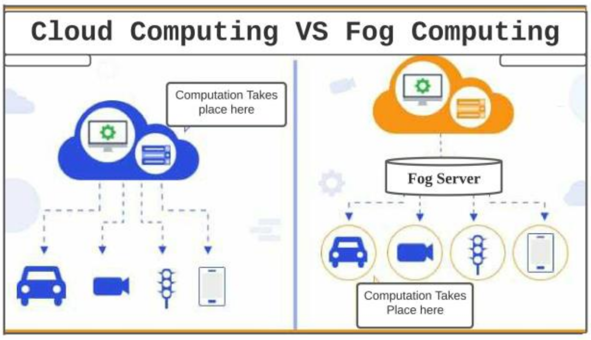


**Fig 3:** Cloud vs Fog Computing

## 3. Features and Challenges

The main motive of cloud computing is to extend quality control to create a CC service and expansion of new forms of applications that can be received in the IoT framework. It collectively improves the QoS for them; achieve low latency and high band through excellent navigation services. A common uniqueness associated with
fog computing is its hierarchical parallel processing operations at the edge of the core network [25, 26]. This means that the computer environment in Fog can prepare for cloud computing.

### 3.1 Features

The characteristics of fog computing are as follows:

(i) Cognition:

Cognition is the ability to respond to the buyer's main goal. Information access and analysis based on fog provides a higher alert regarding consumer necessities, better location management for transmission, storage and cloud management functions up to IoT continuum. Applications, due to close proximity, at end devices provide a better conscious and responsive reproduced customer requirement relation [6].

(ii) Heterogeneity:

Fog computing is also a virtualized structure therefore it offers process, storage, associate degreed networking After all, it is the most important cloud and devices. Its heterogeneity attribute consists of the server it represents hierarchic constructing blocks at dispensed positions.

(iii) Geographical distribution of the environment:

Fog computing environment has a widely circulated deployment in context to provide QoS for both mobiles and motionless end devices [24]. Fog network distributes geographically its nodes and sensors among the state of affairs of various section setting, as an example, temperature monitoring in the chemical warehouse, weather monitoring sensors, STLS sensors and medical system

(iv) The edge location:

The approaching out insufficient power supply units for smart applications the shortage of support at the proximity of devices with QoS provided at the core of the network. Video streaming in small TV support devices, monitoring sensors, live gaming applications, and many more are some examples of applications, which required low latency services in its proximity [28].

(v) Basic interactive measures:

The time of interaction, also varies and the need for fog applications such as appearance essential technique at oilrig with the fog edge Device or sensor, traffic transmission detector systems, electricity distribution watching system applications, then on. Fog applications can handle QoS in real time instead of running it.

(vi) Mobility:

Mobility support is also a necessary fog advantage of changing the process of direct communication between mobile devices pattern SDN protocols that separates host identity from site identity with an expansion indexing system.

(vii) Huge area detector network:

Corresponding function in the fog befitting when environment-monitoring system, in close to sensitive network applications do improve monitoring capabilities system driven by hierarchical computing and storage requirements.

(viii) Extensively used wireless access:

Throughout this state of matter, Wireless Access Protocol (WAP) and cellular gateway are usually typical examples, as fog node is close to the end user.

(ix) Interactivity technology:

Fog elements ought to be able to add interoperating surrounding to make sure assist in providing various services, such as streaming and real-time processing for best information analysis.

These processed functions change the new service and Business model to increase sales and price reduction, or speed up product rollouts among the business and even have focus for fresh investors within the context of fog structure preparation.

### 3.2 Challenges

The challenges are as follows:

(i) Authentication concern:

Authentication techniques are one in all the most problems with security services associated it's so needed in cloud-fog computing design. Before accessing resources, the end user or device should be authenticated to receiver-end (for example, via the server). Authentication plays a very important role, as a result of fog devices can give services when end-user authentication is satisfied and similarly, before granting access to resources, the cloud server must also confirm that the end user's device. These methods are called one-way authentication.

However, because of massive volume of networks and cloud masquerade attack, mutual authentication is equivalently important. Resembling man-in-the-middle attack, it is also very important security problems in mutual authentication protocol, wherever the attacker impersonates as either end user. If this attack happens successfully by the attacker in however ways, the valid entity (end user, fog server) can suffer from obtaining the first message.

(ii) Key Management

Key management is another vital issue and needed for firmly sending information between the cloud and fog servers. For the secure communication between the fog and cloud server, there should be a public key infrastructure (PKI) that gives fog and cloud server keys (encryption, decryption). All the fog devices ought to maintain their own personal key. Similar to anti-fog devices, cloud servers even have to keep up the privacy of the private key. Because these private keys are very important. It is noted that all these keys are needed to ascertain session key for secure communication. If the individual gets of these keys somehow, then he will get all the messages transmitted through insecure channel by establishing the older session keys victimization the protocol description.

In mutual authentication protocol session key should be generated for thereafter-secure communication by encrypting the information using the session key that is transferred between the entities. It is very significant security issue and difficult job that the wrongdoer should not generate valid session key from the general public data of the protocol. It is also equally important that the wrongdoer should not cypher valid session key if the previous session key is revealed in some ways. Therefore, key management is additionally a very important problem in fog-cloud computing model.

(iii) Data Integrity

The abstraction of information integrity confirms that the message received by the receiver-end should be precisely same sent by the sender. It is conjointly one amongst the necessary properties, which is essential for cloud-fog computing model. The end-user usually accesses data from either fog or cloud server and the fog or cloud server provides the specified data to the user, it is necessary to avail integrity of the data. If the end user wants to send data to the fog machine or cloud server, the integrity must also be maintained. One of the present techniques of cryptography known as hash function (Example: SHA-1, SHA-2, MD5, etc.) is utilized to produce integrity property. Many researchers worked to attain sturdy integrity property. Yet, robust integrity is an open challenge for researchers

(iv) Secure data storage

Data storage either in server or cloud in plaintext kind could be a terribly easy issues, however to store data securely. In cloud-fog computing model, the essential data is reserved in fog devices (frequently used data) and additionally in cloud server. In fog computing, information is stored in the fog database for future use but the problem is that the anti-fog device anyway can give security on stored data. Adversary has proficiency or they used high-standard methods that violate the security system. It is assumptive that the data is reserved as plainest in fog device. If it is happening then the adversary will substitute fog device to store essential data. Whereas, many researchers are projected to store the data in encrypted mode in order that they cannot rewrite the data upon obtaining the stored encrypted data. During this regard, the fog devices have to maintain keys for encrypting and decryption. Identical types of problems are there in cloud computing.

(v) Intrusion detection and prevention system

Intrusion detection system (IDS) is important like security attack protection in cloud server for denial-of-service attack, port scanning attack, and flooding attack. Throughout the communication process, malicious users can send extraneous data to the recipient and may send enormous amount of information to the recipient to accomplish DoS or DDoS attack. Hence, it is important and needed to utilize IDS techniques at the fog devices to detect intrusive behavior by observance and analyzing logs file, user information, access management policies and so forth many existing IDS algorithms are available, however still not coherent. Therefore, it is still difficult analysis to style new and efficient formula for IDS. The same construct may be needed at the cloud server like fog devices.

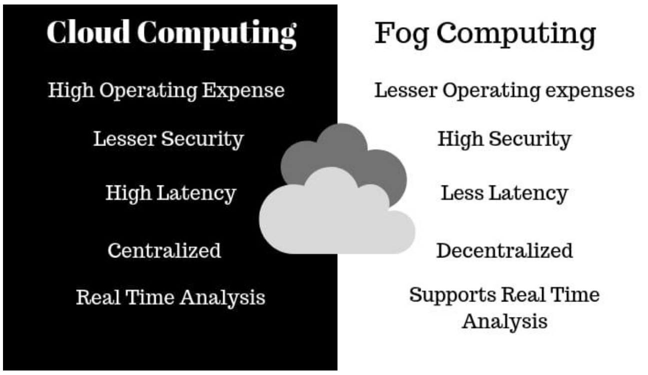


**Fig 4**: Cloud vs Fog Computing

## 4. Applications of Fog Computing

This section brings in many application areas resembling Energy Lattices, Connected Parking System, MediFog (Fog Computing in Healthcare), FoAgro (Fog Computing in Agriculture) and therefore the the} UXFog (Fog Computing in centralized places like searching centers) to debate how these application areas are utilizing the concept of fog computing.

### 4.1 Energy lattices

Energy Lattices are typically the Smart Grids and the design has been projected on the conception of Fog Computing. Cities across the planet are below the scanner of giant pollution rate and enormous energy consumption rate. Proper energy usage and sustainably sustainability energy appears to be the past however with the innovative analysis on the fog computing, it extremely seems to a reality.

Cities having multiple sources of energy resources will have the possibility to choose the most efficient energy resource [29, 30]. Devices such as smart /energy meters and micro-grids automatically shift to an efficient energy resource based on the availability and lowest price [19,20]. These fog collectors will store the information that are generated by the grid sensors and based on the data received it will command the mechanism to decide on a specific energy resource. The foremost appropriate close resource based on the reading of the energy meter are going to be the selection of resource. These sensible grids will typically filter the data needed by the sensors. The end users will be aware of the energy consumptions, pollution rates and these will be the general public data. This data is going to be communicated through internet to the end user. The internal data which is used to choose the appropriate energy resources will be kept as private data and it has to be properly secured through cryptographic mechanisms [22,23,24]

### 4.2 Medifog

MediFog is a computer application in the medical field. Healthcare has always been the emerging need of an hour [20]. This is a very crucial field as it directly involves health of a person. Various technologies have already been proposed for this field [21, 22]. This system proposed can be used to detect and predict any unusual situation of a patient such as cardiac arrest or excessive rise and fall of blood pressure [25]. This knowledge will be captured by a detector and can be sent to the fog servers. The hospitals can have the access of the patient' data and might directly take action. The patient who has registered to a particular hospital, only them data can be viewed by that particular hospital [26]. The patient's do not need to share the data physically with the hospitals, intact the hospitals can access the essential data required whenever the patient needs check-up [27,28,29]

### 4.3 FoAgro

FoAgro is a fog computing application used for agriculture and farming. In countries like India, wherever Farming could be a quite predominant occupation. People make a living through this occupation however; crops are destroyed because of management of the farming lands. A fog computing resource has been projected to resolve this explicit issue. Sensors like moisture sensors, digital camera sensors, etc., are positioned at desirably in farmlands that store the records and send the statistics to the fog nodes/servers. The moisture sensors are going to be ready to calculate the moisture content of the crops and the camera sensors can capture the important time image of the crops and the farm. This data is accessible to a specific farmer, who is that the owner of the involved farmland. On analysing this data, the farmer can take appropriate action on his farmland. This data is kept private and made secure so that no one else gets to access the data [29, 30]

### 4.4 Connected Parking System

Metropolitan Cities, now-a-days face a very horrific drawback with parking. The management of parking spaces in metro cities has always been misused. This problem has been solved to a certain extent by the means of fog computing resources [15-20]. The fog here is placed in piles in the park; the information from the sensors is accumulated at the fog nodes. The users who want to search out the vacant parking spots often see this data. The sensors can change the status of a specific parking spot once it is occupied. This procedure becomes hassle-free for the users who need a vacant parking spot. The users will get to grasp the status of vacant parking spots exploitation Wi-Fi/Internet by accessing the general public knowledge. This is highly required to be made secure as no one should be allowing to change the data from the sensors [11-16]

### 4.5 UXFog

UXFog is that the user expertise fog computing which is enforced typically within the centralized shopping malls that witnesses a large sound on a daily basis. Recently with the increasing population, there has been an ascension of shopping centers. Various services of shopping centers have become an indispensable part of daily life. This is wherever the fog computing comes into the picture [17,18]. There are various fog servers within a store. Precisely, every floor of a shopping mall incorporates a fog server connected. These fog servers collectively form an integrated localized information system [15,16]. The fog servers at each floor contain all the floor-related information like advertisements of stores, offers, pricing, and goods. All these information stored on the fog servers of a particular mall will be available on a mobile phone of an end-user using Wi-Fi/Internet [25].-The info that the end-users can able to read are going to be the general public data. The mall authorities can keep the access of the backend server of the fog nodes at every floor. The users will send response from their mobile phones, whenever there is a demand to send the info. All those data, which are stored at the backend servers are the data, collected from the end users as the private data [26,27]. This private data is generally made highly secured using various cryptographic protocols [20-30] Collectively, all the information of the fog servers will be stored on a centralized cloud data [24,25]

## 5. CONCLUSIONS

Cloud computing technology has been established as another infrastructure of Information Technology (IT) and model. The Internet of Things system is a very complex architecture with almost no storage and operation capabilities. However, as service provisioning infrastructures and centralized resources logically, cloud computing cannot handle local problems appropriately, together with several IoT elements. It is conjointly not responsive enough for the applications that need instant attention of an area. This leads to fog computing. Fog computing has become an extension of the cloud because it is closer to the Internet of Things elements, and data is stored in the cloud and fog nodes. Adding cloud computing and fog computing to many IoT implementations will be beneficial. The documentation presents cloud computing and fog computing, and recommends the use of advanced IoT applications for cloud computing and fog computing. This paper aimed to estimate up-to-date analysis contributions on cloud and Fog computing and IoT and its implementations in the environment. It is also committed to potential research directions and open topics related to the integration of cloud computing and fog computing with the Internet of Things. As a result, Fog computing presents multiple advantages of cloud computing. Besides, it's a superlative locus to deal with performance and problems as a result of its specific services associated resources are virtualized wherever it's set at the network' edge. This paper discusses architecture of fog computing with application domains such as Energy Lattices, MediFog, UXFog, Connected Parking System and so forth within the context of fog devices together with the protection concern at every level of the architecture to stop the malicious access or modification of the data. Further, it mentions potential security concern such as authentication, integrity, secure storage, key management, and IDS in fog devices moreover as in cloud computing.

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