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## Comparison of Fog Computing & Cloud Computing

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### Abstract

Fog computing is extending cloud computing by transferring computation on the edge of networks such as mobile collaborative devices or fixed nodes with built-in data storage, computing, and communication devices. Fog gives focal points of enhanced proficiency, better security, organize data transfer capacity sparing and versatility. With a specific end goal to give imperative subtle elements of Fog registering, we propose attributes of this region and separate from cloud computing research. Cloud computing is developing innovation which gives figuring assets to a specific assignment on pay per utilize. Cloud computing gives benefit three unique models and the cloud gives shoddy; midway oversaw assets for dependable registering for performing required errands. This paper gives correlation and attributes both Fog and cloud computing differs by outline, arrangement, administrations and devices for associations and clients. This comparison shows that Fog provides more flexible infrastructure and better service of data processing by consuming low network bandwidth instead of shifting whole data to the cloud.

**Index Terms:** Cloud computing, Fog computing, Comparison.

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### 1. Introduction

High-performance computing trends changed according to technological innovation and user demands [1]. Previously grid computing was a consideration in the service providers and organization for use of free

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resources for high-performance computing [2]. Currently, the extended version of grid computing is used, named as cloud computing and technology vendors like IBM, Google and Microsoft extending cloud computing with Fog computing. Fog Computing is a progressed or expanded variant of cloud computing where computing happens at the edge of the system. There are numerous organizations as of now spending a considerable measure of research on this point like Cisco and so on. Fog computing defined as in [3], a situation where a support of all of heterogeneous (remote and some of the time self-ruling), universal and decentralized devices convey and conceivably participate between them and with the network to perform capacity and preparing undertakings without the intercession of outsiders. These undertakings can be for supporting essential network capacities or new administrations and applications that keep running in a sandboxed situation. Clients renting some portion of their devices to have these administrations get motivators for doing.

It was assumed by Marketsandmarkets that in the year 2015 cloud or high-performance computing (HPC) produce up to \$4.37 billion and it will increase up to \$10.83 billion in 2020 [4]. The future investment was forecasted up to \$6 trillion for the next five years on IOT solutions and which will also consume on Fog computing the hot topic among the businesses and investors. Technology thinker believes that when Fog computing into the market then data load will not essential for modern cloud computing to carry because IOT with 4G technology endorsed by the organization to enlarge use for solutions that will make more profit and trustworthy.

Our paper is organized into 5 sections, in section 2 we describe the Fog computing and section 3 is based on cloud computing. Section 4 provides a comparison of Fog and cloud computing; finally, in section 5 we conclude our work.

## **2. Fog Computing**

Fog computing is more advanced and its performance better than cloud computing for handling user requests and emerging standards [5]. Cloud computing is infrastructure based and required hardware and software to manage task and processing where Fog utilizes resources of devices on edge but it will not replace cloud computing at present time, which is top of all business and provide employment to the world. It was concluded that cloud computing and Fog computing have own characteristics to process data burdens and preferences but are the supplement to each other [6]. Edge registering assumes a pivotal part of the Internet of Things (IoT) [7]. Security and privacy concerns are also found in the framework of Fog computing which still big issue business point of view as compared to cloud computing. With the help of Fog computing, the ideal model of business will develop which reduce the delay, jitter that will beneficial for fast computing and force to businesses of cloud computing to reduce the cost of processing utilities [8].

Fog computing defined as a progressed or expanded variant of cloud computing where the computing happens at the edge of the system. There are numerous organizations as of now spending a considerable measure of research on this point like Cisco and so on [9, 10].

- It is like cloud computing, however, is far denser in land dissemination what's more, area and its nearness to end clients is more, which implies they give a quicker end-client encounter than distributed computing and have better execution.
- The inquiries concerning its unpredictability, pragmatic attainability, cost and execution are emerging in various research groups. There is likewise a noteworthy concern about its dependability or sturdiness in playing out a wide range of operations performed by distributed computing frameworks.

### *2.1. Characteristics of Fog Computing*

- Low inertness, edge area and area mindfulness: Fog processing arrangement better administrations to

end clients at the edge of the network.

- Geographical Distribution: Fog computing application, objective and services are widely distributed.
- Support for Mobility: Fog figuring give versatility systems like decouple have the personality to area character by utilizing LISP protocol.
- Real time interactions: speedy services need real time interaction in Fog computing.
- Heterogeneity: Fog computing supports heterogeneous devices and support nodes in a wide variety of environments.
- Interoperability: Fog gives a wide range of services so for that purpose Fog devices incorporate for streaming of services.

Fog computing is also known as fogging [11]. Fog computing foundation is distributed, few processes are executed at the edge of the network by intelligent devices and remaining part will shift to cloud for processing. Fog is techniques is utilized devices for data processing, storage from client to cloud and provide the fast network with security to transfer low volume of data for processing to cloud and most of the processing accomplish on the edge devices [12].

Smart lighting system working on the set of instructions is an illustration of the Internet of Things [13]. Data processing may interrupt the results that lights are turned on or turned off when there is no movement for time span in IoT. This data and outcomes are best refined at the outskirts.

The organization executing the Smart lighting framework could likewise wish to venture up towards vitality effectiveness and for perceiving about the ideal opportunity for which the lights were turned on? The information which supports this "whole point of view" of how the keen lighting is being actualized would require information to be requested and prepared by an announcing framework keep running in the cloud [14].

### 3. Cloud Computing

Cloud computing is popular as provide services and computing resources on pay per use to users on their demands [15]. Cloud computing is an extension of cluster and grid computing which was used to collect resources at one central place and utilize them to high-performance computing. Cloud computing architecture provides three types of services such as software as a service (SaaS), Platform as a service (PaaS) and Infrastructure as a Service (IaaS) [16, 54]. NIST gives the definition of cloud that design of computing architecture, which provides high powerful resources for computing, storage, the environment of application development with multiple platforms with ease of management and coordination of all devices of resources at one place [17, 18]. Cloud computing also provide mobility features know as mobile cloud computing. Mobile cloud computing is defined as a *"new worldview for portable applications, where the information handling and storage are relocated from the nearby clients to intense and centralized computing platforms situated in the clouds"* [19]. Cloud computing models are different according to the type of services they provide such as SaaS deals customer services like accounting, database application software and emails but the user did not deal with technical infrastructure of cloud [20, 21]. PaaS provides a platform for application developer like programming environment, by using those tools develop applications and have rights configure and technically manage the cloud [22, 23]. IaaS provides services of the infrastructure of clouds such as manage servers, storage and network devices [24, 25]. IaaS provides the right to manage, change or configure cloud infrastructure according to their needs. Cloud computing models are given in figure 1.

#### 3.1. Cloud Deployment Models

Cloud computing deployed according to four different ways such as public, private, community and hybrid [26, 27].

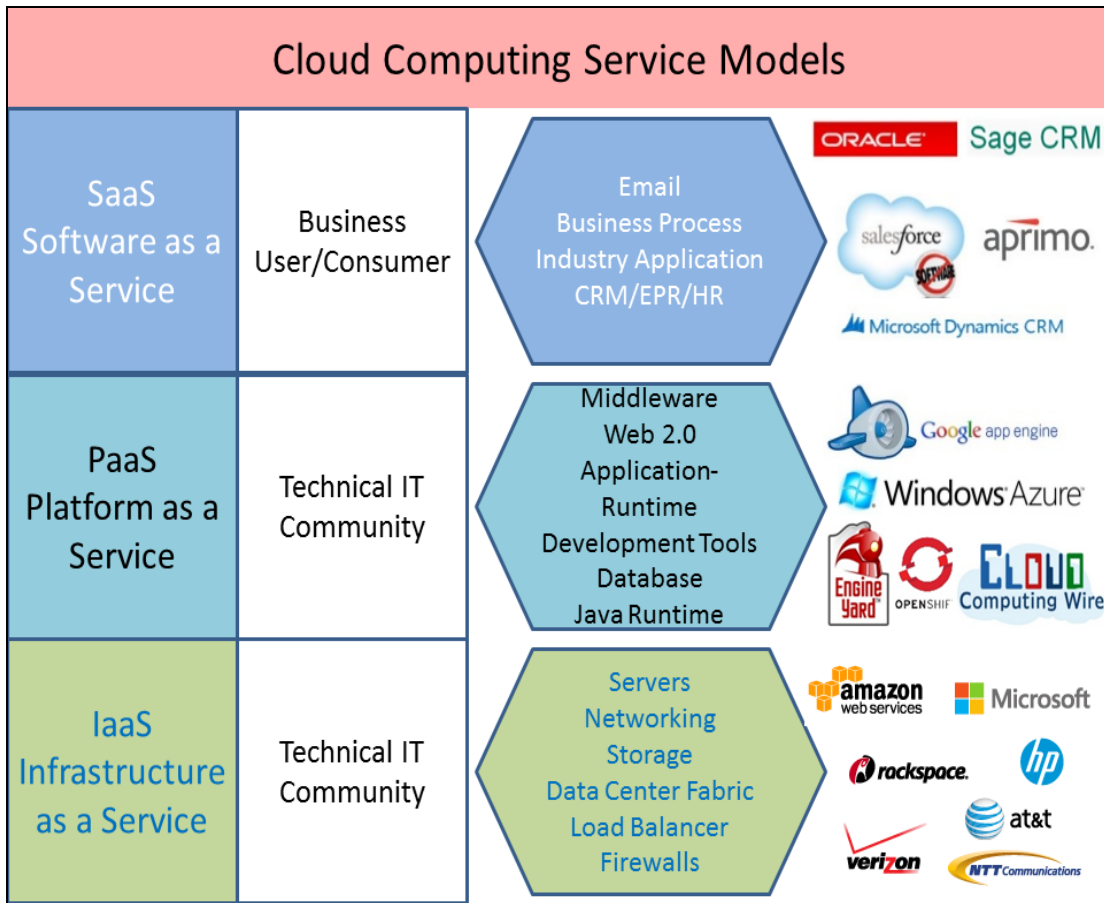


Fig.1. Cloud Computing Service Model [15]

- **Public cloud:** This design of cloud is open for general public use and is designed and managed by government organizations, educational sector or business organizations or combination of some of them, its depend on the service providers [28].
- **Private cloud:** Public cloud is designed and developed for the private use of organizations such as education, business and security agencies or managed by multiple organizations for consumers [29].
- **Community cloud:** the cloud designed and managed by a specific community to use it for security or business purpose. It managed by one or two organizations based on the community [30].
- **Hybrid cloud:** This foundation depends on the arrangement of multiple cloud designs such as public, community, or private which composed to together for empowers computing resources information and application transportability (e.g., cloud blasting for stack adjusting between clouds) [31, 32].

#### 4. Comparison

In this section Fog and cloud computing comparison is given in table 1.

Table 1. Fog vs Cloud Computing

Parameters	Fog Computing	Cloud Computing
Goal	Enhance proficiency and execution of process that should be transported to the cloud for handling, investigation and storage	Give a request of greatness change in the practical, powerful provisioning of IT administrations
Computational focuses	Fog operates on network edge	Data and applications are processed in the Cloud
Abstraction Level	High	High
scalability Degree	High	High
Support of Multitask	Yes	Yes
Level Transparency	High	High
Run time	Real time services	Real time services
Type of Requests	Lots of High allocation	Lots of small allocation
Allocation unit	All shapes and sizes (wide &narrow)	All shapes and sizes (wide &narrow)
Level of Virtualization	Vital	Vital
Accessible type	IP	IP
Transmission	Device to device	Device to Cloud
Security	Possible, determined	Undefined
Infrastructure	Flexible	3 models (PaaS, IaaS, SaaS)
Support of Operating System	hypervisor virtualization	A hypervisor (VM) on which multiple OSs run
Ownership	Multiple	Single
Service negotiation	SLA based	SLA based
Support of User management	Centralized	Centralized or can be delegated to third party
Resource management	Centralized	Centralized/Distributed
Allocation/Scheduling	Centralized	decentralized/centralized
Interoperability	Interoperability between heterogeneous resources.	Web Services (SOAP and REST)
Failure management	rescheduling of failed tasks	Strong (VMs can be easily migrated from one node to other)
Service price	Utility pricing and Pay per use as go	Utility pricing, discounted for larger customers
Type of service	CPU, network, memory, bandwidth, device, storage	IaaS, PaaS, SaaS, Everything as a service
Example of real world	Significant Fog applications involve real-time interactions rather than 228 batch processing.	Amazon Web Service (AWS), Google apps
Response Time	Low	High
Critical object	Service	Service
Number of users	Unlimited	Unlimited
Resource	Unlimited	Unlimited
Future	Next Generation of Internet and computing	Fog Computing

Comparison table shows that few parameters are same for both Fog and cloud such as portable access, virtualization, multitask, transparency, service negotiation, critical object, number of users support and resources provided by [33, 34, 55]. Rest of other parameters Fog computing provide more advance benefits compare to cloud computing such as Fog computing provide a response in a short time but cloud takes high. Other parameters like request type, transmission, security, user management and resource management, scheduling, interoperability, failure management, pricing of services and type of services of Fog computing are better than cloud computing [35, 36, 37, 38]. Table 2 provide details of Fog and cloud applications details where Table 3 about the tools.

## 5. Open Research Issues

From one viewpoint, the improvement of Fog and Edge mists incorporates devoted offices, working framework, organize and middleware strategies to manufacture and work such miniaturized scale server farms that host virtualized registering assets [56]. Then again, the utilization of Fog expects the expansion to current programming models and proposes new deliberations that will enable engineers to outline new applications that take advantage from such enormously conveyed frameworks. The utilization of this approach additionally opens up different difficulties in: security and protection (as a client currently needs to "trust" each smaller scale server farm they interface with), bolster for asset administration for versatile clients who exchange session starting with one miniaturized scale server farm then onto the next, and bolster for "installing" such smaller-scale server farms into gadgets (e.g. autos, structures, and so forth.) [57]. By adding quality of experience (QoE) domain in Fog computing, service will be improved for video streaming and game services [58]. The technical parameters are different in every field such as multimedia services contains bitrate of video, frame rate, video codecs etc. and game required high processing power to adding QoE will provide user stratification about the services [59].

To fulfill the consistently expanding interest for Cloud Computing assets from rising applications, for example, Internet-of-Things (IoT), scholastics and industry specialists are currently pushing for going from substantial unified Cloud Computing foundations to smaller scale server farms situated at the edge of the system. These smaller scale server farms are frequently more like a client (geologically and in getting to dormancy) contrasted with the incorporated cloud server center [60, 61]. The point of using such edge assets is to offload calculation that would have "customarily" been completed at the cloud server center to an asset that is more like a client or edge devices. This vision additionally recognizes the variety in arranging dormancy from an end client to cloud server center. Though the system around a server center is frequently high limit and speed that close to the client devices may have fluid properties (Regarding flexibility, transmission capacity, idleness, and so forth). Cloud and network management are important for service providers to provide QoS to end users, so they can evaluate their services via subjective feedback of users, sometimes which contains inaccurate and negative responses [62, 63]. Therefore, for proper management accurate and positive QoE is required, leading to further work in QoE monitoring and management.

Table 2. Fog and Cloud Computing Applications

Technology	Applications	Comments
Fog	Video streaming, gaming (Rendering and decoding)	It can give huge administrations to video and gaming applications and empower new stream of intelligent multimedia era. It also provides rendering and decoding of multimedia contents [39, 40].
	Small cities, environmental monitoring (Fusion and Aggregation)	Cisco gives an application store which enables clients to download applications to the IOx devices and an application administration comfort which is intended for controlling and observing the execution of an application. It also provides Geo-Distribution and security [41].
	SCV, smart Grid, Int. Transportation (Partitioning/quasi-autonomy, security)	This provides services to federal/state agencies, car manufacturing.
Cloud	Deep data Mining, Search, financial algorithm (MR/Hadoop)	It is used for large batch jobs of data search and analysis and this can be used by individuals or enterprises [42, 43].
	e-commerce (Web applications)	This provides services of shopping, transactions of money for enterprises and also for individuals [44, 45].
	Cloudo	A idle computer System that online on the Internet via web Browser [46].

Table 3. Fog and Cloud Tools

Technology	Tools	Comments
Fog	IFOGSIM	iFogSim empowers the reproduction of asset administration and application planning arrangements crosswise over edge and cloud assets under various situations and conditions [47, 48].
	Fog Project	A free Open-source network computing cloning and management solution [49].
Cloud	CloudSim	CloudSim is used by developers for evaluation of the requirements of large-scale cloud applications [50].
	Zenoss	A solitary, coordinated item that screens the whole IT framework, wherever it is conveyed (physical, virtual, or in cloud) [51, 52].
	Cloudera	An open-source Hadoop programming structure is progressively utilized as a part of cloud computing organizations because of its adaptability with cluster based, information concentrated questions and different tasks [53].

## 6. Conclusion

In this paper, we presented a comparison of Fog and cloud computing this will help to understand the differences between both the researchers. Cloud computing technology now mature and many development tools are available for design and implement cloud infrastructure. Fog computing is an early stage of research and still, prototype models and development tools are under research phase but we believe that Fog computing is future of modern computing technology and evolve very fast and utilized edge of devices for computational resources. The Tables given in paper provides details of advantages which provide of Fog computing over cloud computing. Fog will promising business model for service providers in the future.

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