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# A Comparative Study on Cloud Computing, Edge Computing and Fog Computing

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**Abstract.** In the recent era, Cloud computing has emerged as a high demanding technology. Apart from the cloud computing, edge and fog computing also becoming popular. Cloud computing was developed to provide steady and expansible services to end-users as well as industries. The merger of cloud computing with smart devices brings us into a new version of computing. Presently, Edge computing and fog computing techniques are flattering the world after cloud computing, which has all matured with the limitations in cloud. The objective of this study is to examine the current trends and concepts in detail, also, to provide a comparative study for the fog computing, edge computing, and cloud computing. This study includes few features, application, advantages as well as disadvantages, and the contrast between these technologies and how every one of them is effective for different applications.

**Keywords.** Internet of Things (IoT), Edge Computing, Cloud Computing, Fog Computing.

## 1. Introduction

The current development in the world is based on data-driven applications. These data driven applications gives a huge hike to the advancements in storage and resources. Trends in storage and resources are changed according to technological transformation and user needs. Thus the cloud computing, edge computing, and fog computing infrastructures are being used in various applications that are dependent upon data. Here, our main focus is to study these computing technologies for different kinds of IoT scenarios [1]. Different applications of IoT are generating a massive amount of data from the sensors installed at the different places. These data will be analyzed to meet the objective of the applications. But unfortunately, processing and storing that data is the most tedious task nowadays. In this particular study, we observed that these computing infrastructures differ by their objectives but often complement each other. This lets them meet the different needs of real-time applications [2]. To understand them deeply, each three of them is discussed here in detail.

## 2. Cloud Computing

For data storage and computing resources, via the internet, we can say that cloud computing is an on-demand access infrastructure. It can deliver the resources over the internet as per your requirements [3]. It is also named the "Pay-as-you-go" service. In earlier days, organizations are storing the data in their own PCs and servers. It was becoming very difficult to manage such large physical and on-premises servers. Cloud computing is the solution to all these kinds of problems. Basically, it allows the shifting of computing from local to remote. Cloud computing moves all the heavy computing mechanisms, processes, and data to the remote location in cyberspace. Your data, your work, and the applications are easily available from any mechanism which is connected to the internet, anywhere in the world. Cloud computing provides many basic services. Few well-known services are Infrastructure as a Service (IaaS), Software as a Service (SaaS), and Platform as a Service (PaaS) [4]. Furthermore, cloud computing services avail the users with a plenty of functions like storage, backup, emails, data retrieval, data monitoring, on-demand services, etc. Many of the operations were nearer to cloud computing since it is now a de facto standard in many industries. The key advantage of the cloud-based system is it lets the data to be gathered from different resources and machines, which is approachable anywhere in the world [5].

Cloud Computing is classified in four sub parts like Public Cloud, Private Cloud, Community Cloud, and Hybrid Cloud.

- **Public Cloud:** Here, this specific cloud type is operated for a worldwide usage. It is created and maintained by business consortiums, administrative bodies, the academic institutions, or a combination of few of these, depending upon the service supplier [6].
- **Private Cloud:** Private cloud was invented and created for the personal access of sectors such as business, pedagogy and statutory agencies or it can be used by organizations for customers [7].
- **Community Cloud:** This type of cloud was developed by a particular group of sectors to make use for the safety or for business motive. Based on the community, this type of cloud maintained by few companies [8].
- **Hybrid Cloud:** This type of cloud rely upon the design of more than one cloud such as community, private, or public. The purpose is to make, computing resources, data, and application transportability, stronger [9].

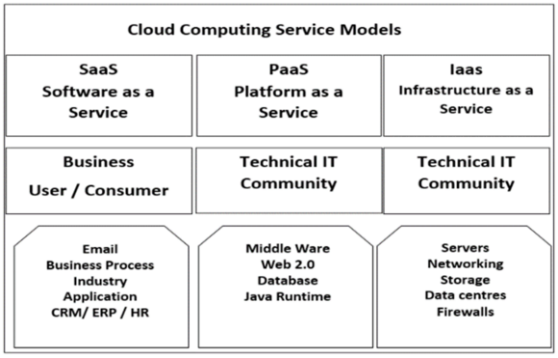


**Figure 1.** Service Model for Cloud Computing [16]

## 3. Edge Computing

Edge Computing suddenly comes into light as the birth of essential to shift the processing to the verge of a network. Though an idea of Edge computing in the market was prior to the cloud computing, but an attentiveness of Edge begins with an increasing popularity of IoT technology [10].
According to [11], ‘‘Processing of data, in Edge computing, will be done at a verge of a network, at bottom side in case of Cloud services and at upside in case of IoT services’’. A concept was to enhance cloud services, at the network-end, to have the processing near to a data sources, i.e., IoT mechanism.
Few features of the Edge computing applications are Aim of extending the functionalities of Cloud to Edge. Cloud services are accessible from different types of networks then also it is dependent on the decentralized framework. Along with that, all the Edge computing applications give a fixed set of benefits like location and context awareness, low latency, mobility assistance, availability, and high scalability [12].
In typical industrial computing, the client endpoint will be producing data, such as a user system. Edge computing setups the servers and storage where the data is. Sometimes needing much more than a half rack of gear to work on the remote LAN to gather and exercise the data nearby [13]. In some situations, the computing tools are positioned in safeguarded enclosures to protect the gear from threshold of temperature, and other atmospheric conditions. Exercise often includes regularizing and examining the information to look for business intelligence, and only the outcome of the review are sent back to the data center [14].

### *3.1 Benefits of Edge Computing*

Though Edge computing provides vibrant architectural challenges like latency, bandwidth limitation, and network traffic, there are many crucial advantages of edge computing that can make a huge difference.
**Sovereignty:** Edge computing is useful when bandwidth and connectivity restrictions are there. Edge computing processes the data at the edge of the network - sometimes on the verge of the device itself. By doing this exercise nearby, the number of data require to be sent can be decreased up to a huge extent.
**Data Independence:** Transferring a large amount of data to the cloud is not just a technical problem. The movement of data across the globe and regional boundaries can cause serious issues like privacy and security. Edge computing helps the data to be stored nearer to its source and within bounds.
**Edge Level Security:** Eventually, Edge computing provides an extra chance to execute and assurance of data safety. By applying the computation near to the device, any data transferring from the network to the cloud can be made secure with the help of encoding and the edge deployment itself can be tough against attacker and other unwanted activities even when the security of the devices remains limited.

## 4. Fog Computing

Implementation of Edge service is mainly describe as Fog computing. Fog service also provides solutions in the sense of distributed computing, storage, control, and networking capabilities. We can say that Fog computing is the better transformation of principles of

edge computing rather than call it as implementations of edge computing. This also integrates the idea of edge by giving a well-mannered intermediary layer which fulfils the breach of IoT and Cloud. Fog computing is not just restricted to compute the data near to the devices. Fog systems may also be deployed at anyplace within the cloud and the end device. It is not actively associated with the end node. In accordance with this, Cloud also uses the services provided by the fog, which implies that it not only focuses on the "things" side. In the continuation with this, we can say that Fog is the structure working in association with the IoT and cloud computing to keep up and improvise their interactivity, to unite IoT, Edge, and Cloud computing rather than an extension of cloud at a verge of the network and not the replacement of cloud itself. [15] [16]

The specific thought behind Fog was described in 2012 by CISCO as ''a strong imaginary platform which delivers processing, storage, and networking services between the edge devices and conventional Cloud computing Data Centers, typically, but not entirely located at a verge of the network." [17]

Fog computing is a framework in which a large unit of miscellaneous, pervasive, and distributed devices transmit and join along with a network to carry out storage and computing functions without the intervention of indirect parties. After analyzing this much literature, it was came to an end that Fog computing is not a centralized approach. Its nature differs from edge computing and it also gives a solution to the centralized nature of cloud computing. Location flexibility in Fog device is also the most essential attribute and it also differs from the applications of edge computing [18] [19]. So that, Fog cannot be taken in consideration as an alternate of typical Cloud infrastructure, instead, a fresh concept which brings IoT, Edge, and Cloud together. [20]

### *4.1 Benefits of Fog Computing*

**Productivity:** Fog infrastructure incorporates the pooling of processing, transmission, storage, and command functions in any place between IoT and cloud. In view of this, the Fog configuration provides potential from the Cloud and takes that from powerful IoT components, uniting all, in the Fog configuration, arising the whole system execution and efficiency [21]

**Agility: Invention of a fresh concept is generally slow and little bit costly**, because of the expense and flow required by huge suppliers to initiate or acquire the transformation. The Fog era, rather, proposes a quick revolution as well as inexpensive scaling, being an unfolded market in which any personals and small-scale groups may utilize a freely available development aid of IoT to propose the new services.

**Reliability:** Fog computing model proposes a brand new outlook on reliability and security. In accordance to this, reliability was observed as a primary development slab of architecture instead of enhanced as well as over-looked attribute to add on a head of it. As a part of this concern, the OpenFog Consortium [20] was very active with the concept of reference architecture of Fog that was having reliability and security as the first pillar.

## 5. Comparison of Cloud Computing, Edge Computing and Fog Computing

Edge computing and Fog computing both working on a functionality that they processes, the data and analysis, nearer to the origin of data or end device or, at the edge or fog node and then transfer the data to the cloud. These two technologies hold the strength of

processing within a confined network to perform an analytical job which may be done by the cloud very efficiently. By applying Edge or Fog computing, one can reduce the dependency for data analytics, data processing as well as storage on the cloud which may lead one to the issue of latency.

**Table 1.** Parametric Comparison of Cloud Computing, Edge Computing, and Fog Computing [7][12][17]

| Parameter | Cloud Computing | Fog Computing | Edge Computing |
|---|---|---|---|
| Architecture | Centralized | Distributed | Distributed |
| Data Processing | Through Internet | Data processed at Fog node | Nearer to the source of data |
| Communication | From a long distance | Directly with the Fog node | At a verge of the network/device |
| Latency | High | Low | Low |
| Computing Ability | Higher | Lower | Middle-level |
| Scalability | Easy to scale | Complex as compare to cloud | Easy as compare to fog |
| Response time | High (In Minutes) | Lower (In Milliseconds) | Average (In seconds) |
| No. of Hopes between device & server | Multiple | One | Depending on the type of application |
| Bandwidth Utilization | High | Lower as compared to cloud | Remarkable reduction in bandwidth |
| Security | Less secured | More secured | More secured than cloud |
| Scope | Global | Limited | Depends upon the type of application |

## 6. Conclusion

Though cloud computing is the better choice for everyone for storage and data processing, organizations are slowly steadily heading towards the edge and fog computing for better efficiency and computing power. The original thought of transforming these two infrastructures was not to replace the cloud entirely but to separate critical information from the original one. With this study, we can conclude that fog computing is more likely to be used by the organizations that deal with data processing. Whereas, Edge computing is recommended by middleware organizations which works as a backend of a network. Ultimately, this review was taken to compare fog computing, cloud computing, and edge computing. Here, our study believe that fog can be the better and efficient solution to the cloud. The future scope includes the usage of correct computing environment for the real time applications.

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