Cloud Computing vs Fog Computing: A Comparative Study

Aviral Kumar Singhal
Student B.Tech.(I.T.), Meerut Institute of Engineering and Technology, Meerut-250005, India
Email: aviralkumarsinghal@gmail.com

Niraj Singhal
Shobhit Institute of Engineering & Technology (Deemed-to-be University), Meerut-250110, India
Email: dmirajsinghal@gmail.com

ABSTRACT

Fog computing (or fogging) is extending cloud computing to the edge of the network. It describes a decentralized computing structure located between the cloud and devices that produce data. Operations like computing, storing and networking between end devices and data centers of cloud computing are facilitated by Fog computing. Decentralization and flexibility are the main difference between Fog computing and Cloud computing. Advantages of Fog computing include, minimize latency, conserve network bandwidth, reduce operating costs, enhance security, improve reliability, deepen insights and boost business agility. Various applications of Fog computing are, smart cities and smart electric grids, smart transportation networks, connected cars, real-time analytics etc. Here, this paper presents a comparative study of Cloud computing and Fog computing.

Keywords - Cloud computing, Fog computing, Decentralization, Internet of Things, Enhanced data security.

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1. INTRODUCTION

Fog computing refers to an alternative to cloud computing. This approach seizes upon the dual problem of the proliferation of computing devices and the opportunity presented by the data those devices generate by locating certain resources and transactions at the edge of a network. By locating these closer to devices, rather than establishing in-cloud channels for utilization and storage, users aggregate bandwidth at access points such as routers. This in turn reduces the overall need for bandwidth, as less data can be transmitted away from data centers, across cloud channels and distances.

Data storage is another important difference between cloud computing and fog computing. In fog computing less data demands immediate cloud storage, so users can instead subject data to strategic compilation and distribution rules designed to boost efficiency and reduce costs. By moving real time analytics into a cloud computing fog located closer to devices, it is easier to capitalize on the existing computing power present in those devices. This improves user experience and reduces burdens on the cloud as a whole. Fog computing is especially important to devices connected to the internet of things (IoT). Decentralization and flexibility are the main difference between fog computing and cloud computing.

Fog computing’s flexible structure enables users to place resources, including applications and the data they produce, in logical locations to enhance performance. It is a way of bringing cloud computing capabilities as a result to the edge of the network and closer to the rapidly growing number of connected devices having desired applications that consume cloud services and generate increasingly massive amounts of data [11]. It is like a decentralized computing infrastructure which computes resources are located between the data source and the cloud or any other data center.

The main goal is to locate some basic analytic services at the edge of the network, closer to wherever needed. This reduces the distance across the network that users must transmit data, improving performance and overall network efficiency. Data storage is another important difference between cloud computing and fog computing. In fog computing less data demands immediate cloud storage, so users can instead subject data to strategic compilation and distribution rules designed to boost efficiency and reduce costs. Fog computing does close the distance between the processing location and the data source, but it does this by conducting edge computing activities within an IoT gateway or fog node with LAN-connected processors or within the LAN hardware itself. The result is more physical distance between the processing and the sensors, yet no additional latency.

Fog computing extends Cloud computing by deploying locally computing and processing facilities into the edge of the network. This yields many benefits including location-awareness, low latency, and on time analytics for mission critical applications. The Fog computing nodes, which represent the resources and infrastructure are located between the physical devices at the network edge and the cloud. The idea is to allow devices to talk directly to each other without the need to send data all the way to the cloud, enabling real-time decisions to be made and also shielding the IoT application from transmitting...
massive amount of data to the cloud. The FC objective is also to connect all devices to the cloud with open communication standards. In this paper, we investigate the characteristics of the Fog computing paradigm and particularly its impact on architecting and designing IoT applications.

It is like a distributed paradigm that can acts as an intermediate layer (between the cloud data centers and Internet of Things (IoT) devices [11]). Through immense connectivity of internet, a number of devices can be easily accessible using IoT technology. For transferring the emerging data fundamentally IoT services has become necessarily colonize. Cloud networks have limitations like of high-latency, poor quality of service. The Industry 4.0 which is the fourth Industrial revolution, is industrial production from a disruptive paradigm which can be capitulated from the Information and Communication Technologies. The integration between cyber physical systems and IoT apparatus is mandatory for the implementation of Fog Computing concepts in Industry 4.0 [1].

2. RELATED WORK

Fog computing, also called fog networking or fogging, describes a decentralized computing structure located between the cloud and devices that produce data. This flexible structure enables users to place resources, including applications and the data they produce, in logical locations to enhance performance. The structure's goal is to locate basic analytic services at the edge of the network, closer to where they are needed. This reduces the distance across the network that users must transmit data, improving performance and overall network efficiency.

Fog computing security issues also provide benefits for users. The fog computing paradigm can segment bandwidth traffic, enabling users to boost security with additional firewalls in the network.

Fog computing maintains some of the features of cloud computing, where it originates. Users may still store applications and data offsite, and pay for not just offsite storage, but also cloud upgrades and maintenance for their data while still using a fog computing model. Their teams will still be able to access data remotely, for example [8].

2.1 FOG COMPUTING

The term fog computing is associated with Cisco, who registered the name 'Cisco Fog Computing,' which played on cloud computing as in the clouds are up in the sky, and the fog refers to the clouds down close to the ground. In 2015, an Open Fog Consortium was created with its founding members Cisco, Dell, ARM, Intel, Microsoft and Princeton University, and additional contributing members including GE, Hitachi and Foxconn. IBM introduced the closely allied, and mostly synonymous (although in some situations not exactly) term 'edge computing' [5]. Fog is a type of architecture that can also link cloud computing to the Internet of Things [6]. The transmission between IoT devices and cloud services is allowed for faster processing.

Fog Computing is a wireless distributed computing platform in which complex latency sensitivity tasks can be processed via a group of sharing resources at IoT gateway level in a locality. In another definition by [7], Fog Computing is "a horizontal architecture on system-level that distributes computation, storage, control and networking capabilities closer to users along a cloud-to-device continuum" [2]. For one approach to edge computing, fog computing is simply considered as Cisco brand [3]. It also defined in words to meet the objectives of equal notions. Internet of things (IoT) also guarantees to implement high-range functions which are related to homes, smart works of automation of vehicles. To increase the amount of requirements and possibilities evaluation, IoT needs a maturing creativity to make the application much reliable at gateway functionalities [1].

2.2. WORKING OF FOG COMPUTING

Depending on the applications of Fog Computing, it can have a variety of components and functions [9]. The complements of Fog networking not replaces cloud computing, cloud performs resource-intensive, longer-term analytics while fogging allows for short-term analytics at the edge [3]. Fog computing puts one and one together [6]. Fog computing implementation involves either writing or porting IoT applications at the network edge for fog nodes using fog computing software, a package fog computing program, or other tools. Those nodes closest to the edge, or edge nodes, take in the data from other edge devices such as routers or modems, and then direct whatever data they take in to the optimal location for analysis. In connecting fog and cloud computing networks, administrators will assess which data is most time-sensitive. The most critically time-sensitive data should be analyzed as close as possible to where it is generated, within verified control loops. The system will then pass data that can wait longer to be analyzed to an aggregation node. It also includes computing gateways that can accept data from data sources and endpoints such as routers and switches, connecting devices of the network [9]. The characteristics of fog computing simply dictate that each type of data determines which fog node is the ideal location for analysis, depending on the ultimate goals for the analysis, the type of data, and the immediate needs of the user [8]. The amount of information is limited that needs to be sent to the cloud for processing because of data analyzing and parsing occurs in a smart hub; gateway, or router [6].

Using fog computing, the process of transferring data includes various steps. The automation controller reads the signals from the IoT devices. Then, the controller executes the system program which are needed to automate the IoT devices. The control system program then sends the data through a standard OPC (an interoperability standard for data exchange in IoT.) This data is then converted into a protocol such as MQTT or HTTP(S) that can be understood by internet-based service providers. Once it is converted, the data is then sent to a fog node or IoT gateway. These endpoints will collect the data for further
analysis or for further transferring the data sets to the cloud for broader usage [9].

2.3. ADVANTAGES OF FOG COMPUTING

A low-latency network connection between devices and analytics endpoints can be created by Fog computing. It must be processed close to where it is created because there is no bandwidth connection to send data [4]. Various advantages of Fog computing are, Minimize latency, Conserve network bandwidth, Reduce operating costs, Enhance security, Improve reliability, Deepen insights, without sacrificing privacy, Boost business agility, Fog computing challenges include a heavy reliance on data transport [8], Better control of privacy, Improved business agility, Low latency [10], Enhanced data security [6], Lower operating expense [10], Greater business agility, Better security, Geographical and giant-scale distribution and Flexibility & heterogeneity [1].

2.4. DIS-ADVANTAGES OF FOG COMPUTING

Several disadvantages of fog computing are elaborated here. Trust and authentication are major concerns. Encryption algorithms and security policies make it more difficult for arbitrary devices to exchange data. Scheduling is complex as tasks can be moved between client devices, fog nodes and back end cloud servers. Fog nodes have high Power consumption as compare to centralized cloud architecture. Any mistakes in security algorithms lead to exposure of data to the hackers. Other security issues are IP address spoofing, man in the middle attacks, wireless network security etc. Fog computing will realize global storage concept with infinite size and speed of local storage but data management is a challenge. In Fog Computing achieving high data consistency is very challenging and requires more efforts [12].

2.5. CHALLENGES OF FOG COMPUTING

Some challenges of fog computing are as follows:-

- **Trust issues and Authentication**: Since these services are offered at a large scale. Hence, the most concerned issue of Fog is Authentication [14].
- **Scalability**: A large amount of data is generated by IoT devices as they are manageable under Fog. Consequently, to process more power and storage, a huge amount of resources are required for fog servers [1].
- **Security**: Since there are many devices connected to fog nodes at different levels of gateways the issues can be arise by Fog computing. Any hacker can fake your IP address and since each device has a different IP address, hacker can access to any fog node which is having personal information that is stored in that fog node [14].
- **Latency**: Latency issues can be overcome by Fog computing. There are several unit factors for presenting a high latency applications towards the application performance [1].
- **Privacy**: There is a huge concern regarding network privacy because Fog computing is based on wireless technology.
- **Energy consumption**: The energy consumption is very high in Fog computing as the number of fog nodes present in the fog environment are high and require higher energy to work. So there is a requirement that the energy required by the Fog nodes should be minimized so that they should become more energy-efficient and can save costs [14].
- **Dynamicity**: As mobility is supported by Fog so the required nodes can adopt their structure independently. Because of this dynamical workflow the performance becomes complicated [1].
- **Fog Servers**: For delivering the maximum service, Fog servers should be at the right placement [14].
- **Complexity**: Since the selection of optimal components is very complicated so many IoT device are designed by various manufacturers.
- **Security**: Because of mobility, heterogeneity Security providence cannot be directly applicable to fog. For enhancing the network to safeguard the cryptography format is very important.
- **Resource management**: For efficient operation analysis through fog servers the smart management of fog resources can be needed.
- **Heterogeneity**: As per the application resources Co-ordination and Management of networks has become a key challenge [1].

2.6. APPLICATIONS OF FOG COMPUTING

Various applications of Fog computing are as follows:-

- **IoT in Industrial**: Fog computing can rely on manufacturing plants to obtain and also process the data [1].
- **Smart/Connected car manufacturers**: Fog computing is also capable to help in real-time transmission of data like some of the driving conditions, traffic situation, and directions. With better connectivity, reduction of accidents can be promoted with safe driving. The information can be transported quickly back to manufactures for further monitoring [6].
- **Smart Home**: Fog computing gives some benefits for home security applications. It also provides the springy resources to change the properties of geo-distribution.
- **Increased Reality**: Virtual reality (VR) adds a virtual data to the platforms of the world. Because of having small devices, storage
compatibility VR becomes a crucial application [1].

- **Smart Traffic**: Traffic sensing flashing lights can be performed with the help of fog computing concept for sensing the presence of pedestrians and cyclists. It also used to measure the speed and space of the vehicle which are close to the traffic lights.

- **Cyber-Physical Systems and IoT**: The globe can also be converted into any computer-based physical reality by using the combination of IoT and Cyber-Physical systems.

- **Real-time analytics**: The deployments of Fog computing can also help to facilitate any kind of transfer of data between where it is created and a various places where it needs to go [4].

- **Smart grids and cities**: In smart cities, real-time, the accurate data is essential for systems to run effectively and smoothly. By Fog, the data travels faster from different sensors. As such, any kind of issues that may arise can be quickly addressed [6]. Sometimes in remote areas this data, so processing close to where it is created is essential. Other times, from a large number of sensors/devices these data needs to be combined. Both of these issues can be devised by Fog computing architectures [4].

- **Activity chase and Health care**: In health care the concept of Fog computing is very important. It provides responses and the data evaluation that measure essential in health care.

### 3. CLOUD COMPUTING VERSUS FOG COMPUTING

Cloud computing and Fog concepts are different with each other on some parameters. Cloud architecture is centralized and consists of large data centres that can be located around the globe, a thousand miles away from client devices whereas Fog architecture is distributed and consists of millions of small nodes located as close to client devices as possible. Fog acts as a mediator between data centres and hardware, and hence it is closer to end-users. If there is no fog layer, the cloud communicates with devices directly, which is time-consuming. In cloud computing, data processing takes place in remote data centres. Fog processing and storage are done on the edge of the network close to the source of information, which is crucial for real-time control. Cloud is more powerful than fog regarding computing capabilities and storage capacity. The cloud consists of a few large server nodes. Fog includes millions of small nodes. Fog performs short-term edge analysis due to instant responsiveness, while the cloud aims for long-term deep analysis due to slower responsiveness. Fog provides low latency; cloud-high latency. A cloud system collapses without an Internet connection. Fog computing uses various protocols and standards, so the risk of failure is much lower. Fog is a more secure system than the cloud due to its distributed architecture.

A comparison of Cloud computing with Fog computing is shown below in Table 1.

**Table 1 - Cloud computing vs Fog computing**

| Requirements                  | Cloud Computing | Fog Computing |
|-------------------------------|-----------------|---------------|
| Analysis                      | Long-term       | Short term    |
| Architecture                  | Centralized     | Distributed   |
| Attack on data enroute        | High probability| Low probability|
| Capacity                      | Does not provide any reduction in data while sending or transforming data | Reduces the amount of data sent to cloud computing. |
| Communication with Devices    | From a Distance | Directly from the Edge |
| Computing capabilities        | Higher          | Lower         |
| Connectivity                  | Internet        | Various protocols and standards |
| Data Processing               | Far from the source of information | Close to the source of information |
| Data Integration              | Multiple data sources can be integrated | Multiple data sources and devices can be integrated |
| Delay Jitter                  | High            | Very Low     |
| Distance between server and client | Multiple hops | One hop |
| Geo-distribution              | Centralized     | Distributed   |
| Latency                       | High            | Low           |
| Location awareness            | Partially supported | Yes |
| Mobility                      | Limited         | Supported     |
| No. of server nodes           | few             | Very large    |
| Real time interactions        | Supported       | Supported     |
| Responsiveness                | Low             | High          |
4. CONCLUSION

Fog computing is a decentralized computing infrastructure which computes resources that are located between the data source and the cloud or any other data center. This computing paradigm can segment bandwidth traffic, enabling users to boost security with additional firewalls in the network. It provides a distributed paradigm that can act as an intermediate layer between cloud data centers and IoT devices. Fog computing extends Cloud computing by deploying locally computing and processing facilities into the edge of the network. This flexible structure enables users to place resources, including applications and the data they produce, in logical locations to enhance performance. Depending on the applications of Fog Computing, it can have a variety of components and functions. This paper has provided a comparison between cloud computing and fog computing, advantages and disadvantages of fog computing followed by challenges and applications of fog computing.

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Authors Biographies

**Asiral Kumar Singhal** is pursuing his B.Tech. (Information Technology) from Meerut Institute of Engineering and Technology, Meerut (affiliated with AKTU, Lucknow). His interest includes, leading and coordinating co-curricular events, computer programming, and learning & working on the latest technologies.

**Dr. Niraj Singhal** is Ph.D. (Computer Engineering and Information Technology). He is Fellow and member of several International/National bodies and, reviewer and member of the advisory board for several International/National journals. He has many research publications to his credit in National/International journals/conferences of repute. He has several years of rich experience of administration, coordinating and teaching at various levels. Presently he is working as Professor in the department of Computer Science and Engineering at Shobhit Institute of Engineering & Technology (Deemed-to-be University), Meerut. His area of interest includes system software, web information retrieval and software agents.