Fog computing and Edge computing: An edge over cloud computing

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Abstract: IoT and its applications are assumed to be as rich source of data. On daily basis, devices come across the internet to exchange information and thus gather, store information from nearby environment to process accordingly. Cloud computing can store massive amount of information that can be anywhere and anytime in the world. Data can be accessed adequately due to its high computation and storage power. Cloud computing model is centralized in nature. Therefore, cloud architecture is not able to respond to low latency and high mobility requirements. There are various challenges high response time, high bandwidth that had emerged in cloud architecture. And to resolve these challenges, new technologies like fog computing and edge computing has been emerged. In this paper, cloud technology has been compared with fog computing and edge computing model. This paper is divided into two parts. The first part contains characteristics of fog computing, cloud computing and edge computing.The second part contains the difference among all the computing paradigms.

1. Introduction

In today's world, massive amount of data is being generated by sensors and IoT devices. Cloud computing proved to be affordable to individuals and organizations by offering efficient and highly available resources. Cloud is not much suitable for the location and latency-sensitive applications such as IoT and connected vehicles[1].The data generated from sensors needs to be stored in cloud and as the data outreach cloud system for computation, the time to take action by actuator or IoT device may be gone. For eg consider healthcare system, where latency plays a major role and action need to be taken immediately [2]. Fog computing follows decentralized architecture which enhances real-time applications by providing low latency and location awareness facility. If server in the traditional client-server architecture becomes overloaded, many devices linked will be unserviceable. This is achieved by creating a new hierarchically distributed and local platform between the Cloud system and end-user devices [3]. Fog computing and Edge computing is supposed to be extension to cloud computing architecture. They both do the computation task on the edge of network. The difference lies in the location where the computation occurs. Cloud computing supports centralization storage and on the other hand, fog and edge technologies have decentralized storage and computation. In real-time applications, Edge computing and Fog computing could help to enhance the quality of service (QoS) by providing low latency, location awareness, low bandwidth consumption and better response time [4]. In both the technologies, data and computation are put close to the end user [5].

Fog computing and Edge computing are sometimes interchangeable but fog computing is inclined towards infrastructure side, while edge computing more towards thing side. So, Edge computing usually occurs directly on the devices to which the sensors are attached or a gateway device that is physically "close" to the sensors.

2. Literature survey

S.No	Authors	Objective
A1	Tuli et al., 2020	New directions to investigate emerging technologies and paradigms on the advancement of healthcare holding next-generation computing systems
A2	Kumar et al., 2020	Improvement in using low-cost energy minimum selection algorithm for routing the data packets.
A3	Geetha et al., 2020	Issues related to efficiency of energy and latency requirement for real time bases IoT applications.
A4	Rana*et al.*, 2020	Fog computing with IoT favoring framework with less energy consumption.
A5	Khaloufi et al., 2020	Three-layer architecture of fog-based healthcare system containing: edge, fog, and cloud in medical healthcare.
A6	Basset et al., 2020	Algorithms based on metaheuristic approach to measure performance in health care management.

A7	Kovačević et al., 2020	Machine learning techniques to handle infant incubators in healthcare institutions.
A8	Xie et al., 2020	The data evaluation method to upgrade the regulation in prediction and collection of data.
A9	La *et al*., 2020	Geographic location creates an array of fog nodes in the system which is defined as hybrid of fog computing used along with IoT.
A10	Harish et al., 2020	Goals, challenges, supported observations, future directions for analysis for fog computing
A11	Prasad et al., 2019	Three layer privacy and usage of fog computing.
A12	Atlam et al., 2018	Open issues, architecture and future research directions of the fog and emerging IoT applications.
A13	Mutlang et al., 2018	Low latency and response time as a concern area in healthcare applications.
A14	Ai et al., 2018	Comparison of edge computing technologies, namely fog computing, cloud computing and mobile edge computing.
A15	Khan et al., 2017	Identification of common security gaps in fog computing application.
A16	Shi et al., 2016	The concerns like bandwidth, batter life, data safety and privacy are addressed by edge computing.

3. Edge computing

Edge computing as the name indicates performs the computation at the verge of the network. This technology allows computation to be implemented at the edge. The computation in edge will be done on behalf of cloud on downstream data and on the behalf of upstream data for IoT devices. But edge computing is more towards thing side and fog computing towards infrastructure side. Computation will be done on the devices in edge computing where sensors are attached. Edge technology can perform caching, processing, data storage services. In addition, to these jobs in network, edge network has been designed to meet some requirements such as privacy, security and reliability. It can assumed that edge computing could have big impact on society.

3.1 Characteristics of Edge computing:

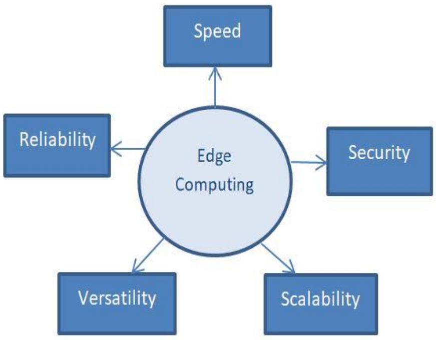

Figure 1: Characteristics of Fog computing

Speed: There are many companies that consider speed as very important factor for their core business. For e. g, in healthcare system, losing even a fraction of second could be life critical. In data-driven businesses lagging speeds sometimes frustrate customer. Edge computing helps to reduce latency and enhances the performance of network by processing data locally on edge devices.

Security: Traditional cloud computing technology is more prone to denial of service attack due to its centralized architecture. Other side, edge computing distributes application, storage and processing across different range of devices. Since mostly data rather than transmitting back to central data server will be processed on local servers and eventually reduces the risk of compromising the data.

Scalability: As the companies grow, it is no longer required to establish private and centralized data centers. Due to edge computing, it is much easy for the companies to scale their operations. The idea of not relying centralized infrastructure that allows them to scale their data and computing quickly and more efficiently.

Versatility: Different companies can effortlessly target preferable markets without investing much in expensive infrastructure. Edge data centers could efficiently provide services to end users with low latency. Edge computing helps IoT devices to accumulate large amount of actionable data.

Reliability: In edge computing, edge data centers are positioned much closer to end users that inhibit less chances of network problem. There are multiple edge nodes that are connected to network and if any failure occurs that would not let interrupt the whole services. There are multiple ways through which that can be rerouted. Edge architecture that comprises of edge computing devices and data centers can help to provide unparalleled reliability**.**

4. Fog computing

Fog means near to ground, this way data and computation task has been put closer to end fog computing [5]. Fog computing and edge computing serves the same purpose of attaching the computing capabilities within local area network effectively that was earlier carried out in the cloud. The data must be aggregated and filtered in fog before the data could be transmitted to cloud. This way IoT and cloud interconnects each other to perform particular processing using fog computing [6]. Fog computing layer comes in between IoT devices and cloud computing which operate data locally from device to fog nodes and then send data to cloud. Fog nodes have their own storage, computing and networking services [7]. Fog computing does all the activities as similar to Edge computing but physically more distant from sensors enabled IoT devices. Fog computing shifts the activities of edge computing to the processors that are connected to LAN

4.1 Characteristics of fog computing includes:

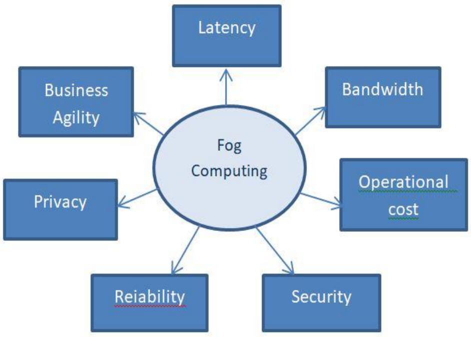

Figure 2: Characteristics of Fog computing

Latency: Especially in verticals where every second counts, keeping analysis closer to the data source prevents manufacturing line shutting-down, cascading system failures, and other considerableissues. The capability to conduct real-time data analysis means faster alerts to the user and less danger for users and time lost.

Bandwidth: Enormous amount of data has been generated from IoT devices. The same data needs to be transferred from one place to another for further processing. The requirement to transfer massive data can be eliminated by technology named Fog computing, which in result saves the bandwidth requirement.

Operating costs: The data that has been generated from IoT devices will be processed locally which will conserve network bandwidth and ultimately reduce the operating cost**.**

Security: Fog computing provides more security as the acquired data will be processed in different numbers of nodes and the computation in the nodes occurs locally that enhances the security in the system.

Reliability: IoT devices are installed in different environmental conditions that can be harsh. Even in harsh environmental conditions, fog computing succeeded to improve reliability by decreasing the load of data transmission.

Privacy: Data breach mostly occurs in cloud. In fog computing, instead of risking data by sending it to cloud, sensitive data could be analyzed locally in the devices that collect and store the data.

Business agility: Businesses cananswer to consumer demand quickly. Fog computing let the developers to develop and deploy fog applications rapidly according to the need of users.

5. Cloud computing

Cloud computing provide resources on pay per use to users on their demands. It helps to provide services and computing resources to users as per their requirement. [8]. Cloud computing issupposed to be an extension of grid and cluster. There are three services generally named as Infrastructure as a Service (SaaS) , Platform as a service (PaaS) and software as a service (SaaS) as provided by cloud computing infrastructure[9].As the definition gievn by NIST, cloud architecture is one of the technology that provides powerful resources for computation, storage and application development environment [10].

5.1 Characteristics of cloud computing

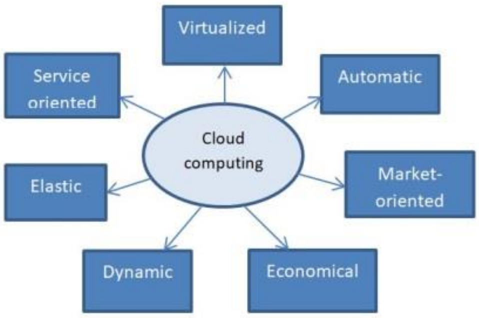

Figure 3: Characteristics of cloud computing

Virtualized: All the resources in cloud service i.e. networking, computing, and storage are virtualized. While running on the same physical machine, applications can run within their operating systems. Migration of application can be easily done from one physical server to another.

Service-Oriented: Cloud generally provides everything as a service. Services like infrastructures, software, and platform made accessible over the network. Cloud is generally implemented using SOA(Service-Oriented Architecture) model, to attain this facility. It's called service oriented infrastructure, because from this paradigm cloud can be benefitted in developing any of its services such as infrastructure.

Elastic: Cloud allows varying of resources allocated for its application and provides the pliancy for dynamically provision. The resources provided by cloud i.e. storage, network capacity increases or decreases according to user QoS requirements at runtime.

Dynamic: Cloud allows the resources to be shared among multiple users. So according to applications de mand, the resources can be dynamically allocated. The dynamic resources and can be increased or decreased.

Economy of scale: Cloud computing is technology that proved helpful in the economic and business models for consuming IT that can lead to a noteworthy cost saving. By resource pooling, the cost saving can be accomplished; this capability makes the resource shared among the users generally.

Market-Oriented: Cloud works on the principle of "pay as you go". Cloud computing is developed much like a utility, so that even the smallest business can afford it. Payment is done by the users only for the services that are used.

Autonomic: Generally cloud service architecture are much dependent. But sometimes, cloud manages their failure or performance deprivation by itself.

6. Comparison

Cloud computing has proved to be greatly developed technology for resource sharing and computation. In this, storage, computing and network management functions work centrally.With the emerging trend of IoT and mobile internet, existing centralized architecture of cloud experienced severe challenge such as response time, security, capacity and low latencyThe centralized architecture was then disintegrated by advanced cloud computing paradigm that subside many challenges. There are three locations where the data can be processed that have been generated form IoT devices: network, cloud and device itself. It will take lot of time to analyze the data if it is processed in the cloud. So there is a requirement to process the data either in the device or the network to enhance the computation speed so the effective decision could be taken on time in real-life applications. The primary aim of the edge and fog computing technology is to minimize latency, and still dependent on cloud to analyse data.

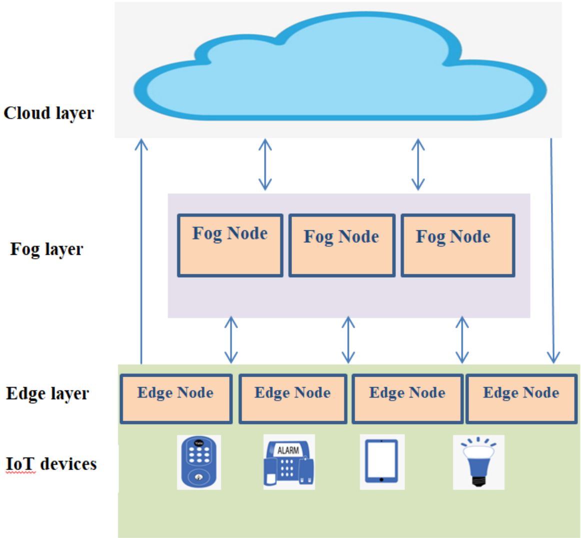

Figure 4: Data flow between cloud, fog and edge

The difference between fog computing and edge computing is mainly associated with the location where the data will be processed. Both the computing technologies seems to be interchangeable to each other but the focus of fog computing is towards infrastructure side while edge computing is more towards device. In edge computing, the processing of data is generally done on the devices or gateway devices closest to the sensors. While in fog computing technology, the same data will be processed in the processors linked to local area network or into the hardware of LAN. The comparison among three technologies named: cloud computing, fog computing and edge computing has been shown in Table 1.

S.No	Parameters	Cloud computing	Fog computing	Edge computing
1	Latency	High	Low	Low
2	Energy consumption	High	Low	Low
3	Response time	High	Low	Low
4	Bandwidth utility	High	Low	Low
5	Data processing	Central cloud server	Within LAN area	On sensor or device
6	Security	Low	High	High
7	Location awareness	No	Yes	Yes
8	Geographically location	Distant	Local	local
9	Architecture	Centralized	Distributed	Distributed
10	Real-time interactions	No	Yes	Yes
11	Mobility	Limited support	Supported	Supported

12	Nodes	Central server	Fog nodes	Edge nodes
13	No. of server nodes	Single	Multiple	Multiple
14	Service Type	Information collected worldwide globally	Localized information	Localized information
15	Working Environment	Indoors with huge space	Outdoors	Outdoors
16	Storage duration	Long duration	short duration	short duration
17	Major service provider	Amazon, Microsoft, IBM	Cisco IOx	IBM
18	Target users	General internet users	Mobile users	Mobile users
19	Storage capability	High	Low	Low
20	Processing power	High	Low	Low
21	Data Analysis	Long in-depth data analysis	Quick analysis	Quick analysis
22	Internet requirement	24 X 7 required	Can work without internet	Can work without internet
23	Data distribution	Centralized server	Among nodes	Data remains on device
24	Downtime	Maximum	Minimum	Minimum
25	Decisive nature	Decision delay	Quick decision	Quick decision
26	Data manipulation	Easy	Difficult	Difficult
27	Security	Low	High	High
28	Downtime	More	Less	Less
29	Management	Services provider	Local business	Local business
30	Energy conservation	No	Yes	Yes
31	Scalability	Low	High	High
32	Distance To users	Large	Small	Very small
33	Backhaul usage	Frequent	Infrequent	Infrequent
34	Applications	Delay tolerant and computation insensitive	Latency sensitive	Latency sensitive
35	Ownership	Central ownership by amazon, yahoo	Local business owner	Local business owner
36	Server hardware	Highly capable servers	Small scale servers	Small scale servers
37	Deployment cost	High	Low	Low
38	Server density	Low	High	High
39	Inter node communication	N/A	Supported	Supported
40	Hardware	Server	Server, End devices	Server, End devices

41	Sharing population	Large	Small	Small
42	Hardware	High storage and computing power	Low storage and computing power	Low storage and computing power
43	Server nodes location	Within the Internet	Within local network	Within local network
44	Distance between client and server	Multiple hops	One hop	One hop
45	Abstraction level	High	High	High
46	Multitasking	Yes	Yes	Yes
47	Transparency level	High	High	High
48	Transmission	Device to cloud	Device to device	Device to device
49	Response time	High	Low	Low
50	Resource mgmt	Centralized	Distributed	Distributed
51	Allocation	Centralized	Distributed	Distributed

Table 1: Comparison among cloud, fog and edge

Fog computing and Edge computing, an extension of cloud computing services to the edge of the network to decrease network congestion and latency. Although purpose of these technologies is to provide resources are services to the user. But fog and edge computing is characterized by low latency with the nodes distributed geographically to support real-time interaction and user mobility. Both technologies widen the utility of cloud computing in the vicinity of the end user. Like fog computing, edge also contains server nodes and end-user devices.

7. Conclusion

Cloud computing has been greatly and efficiently used for the providing platform for data computation and storage. Fog computing and Edge computing is not supposed to be the replacement for cloud computing. These technology works along with cloud to overcome the challenges occurred in cloud technology.

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